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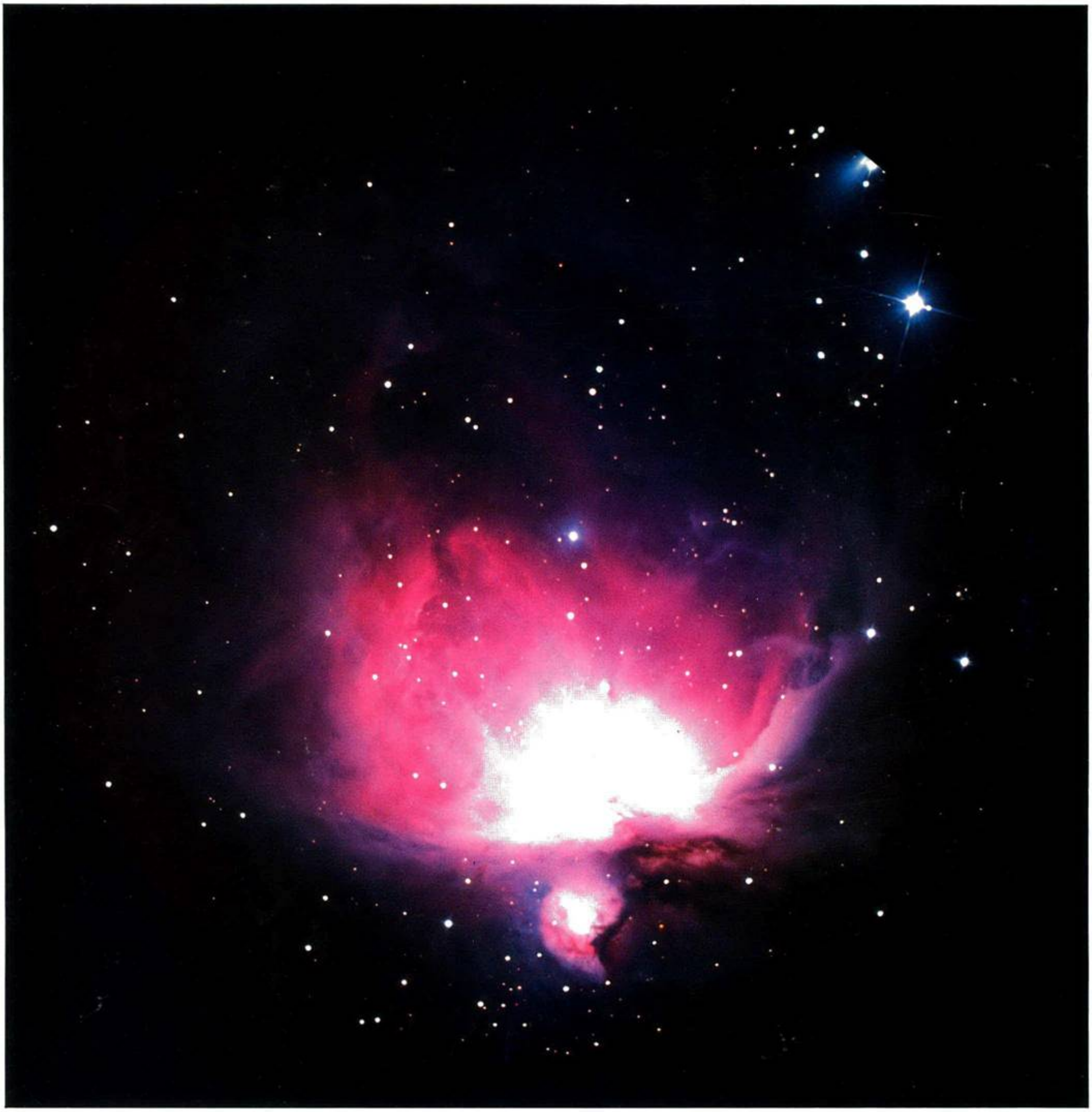

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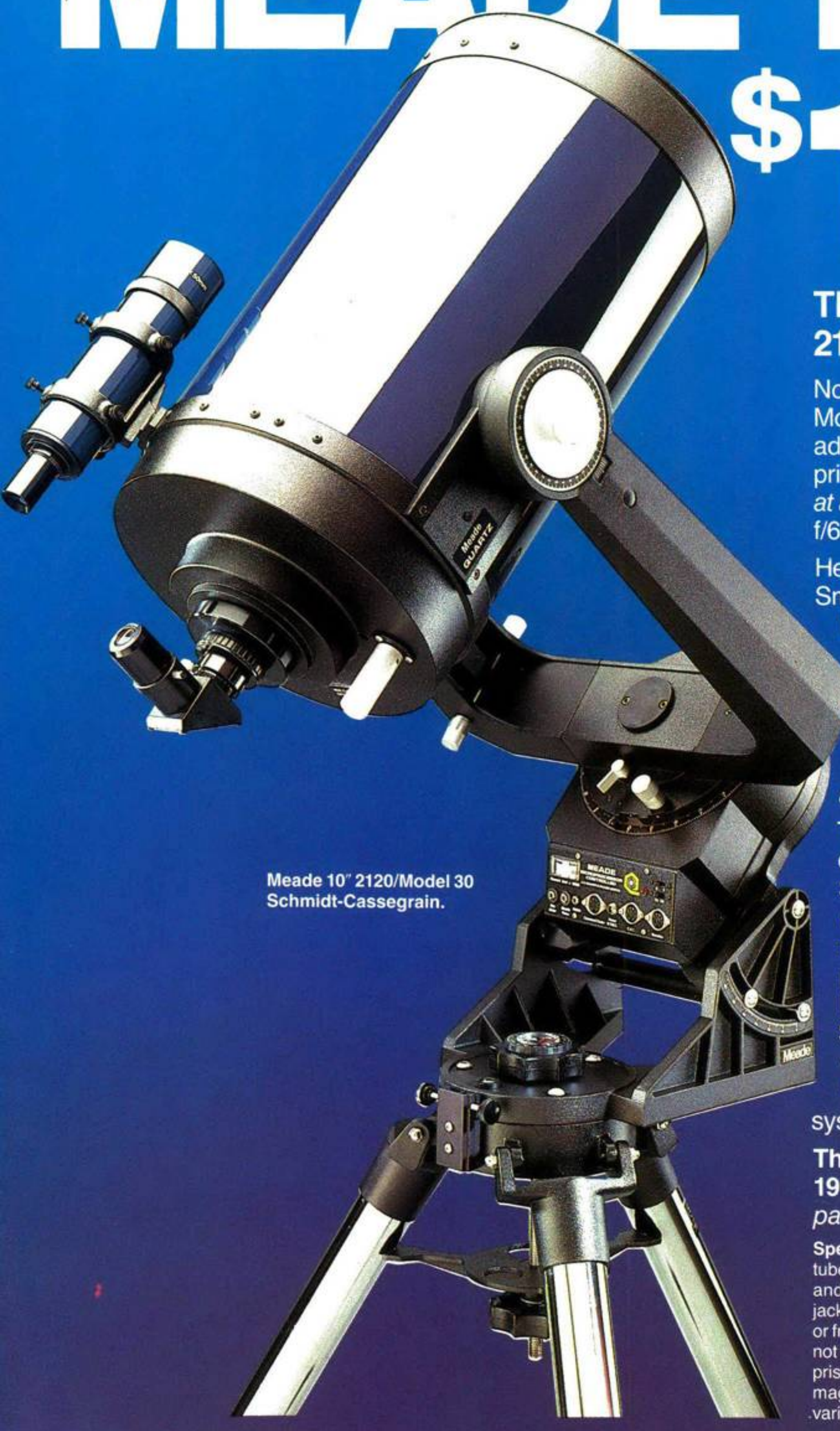

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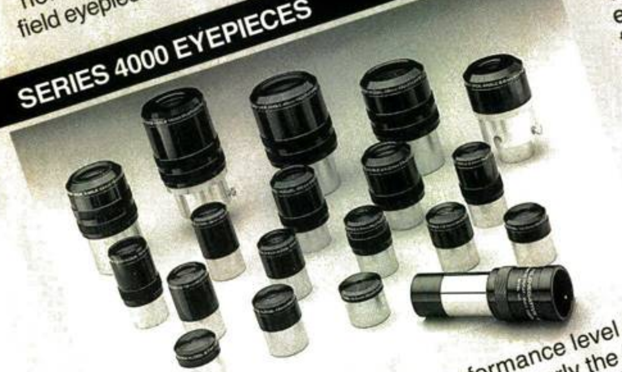

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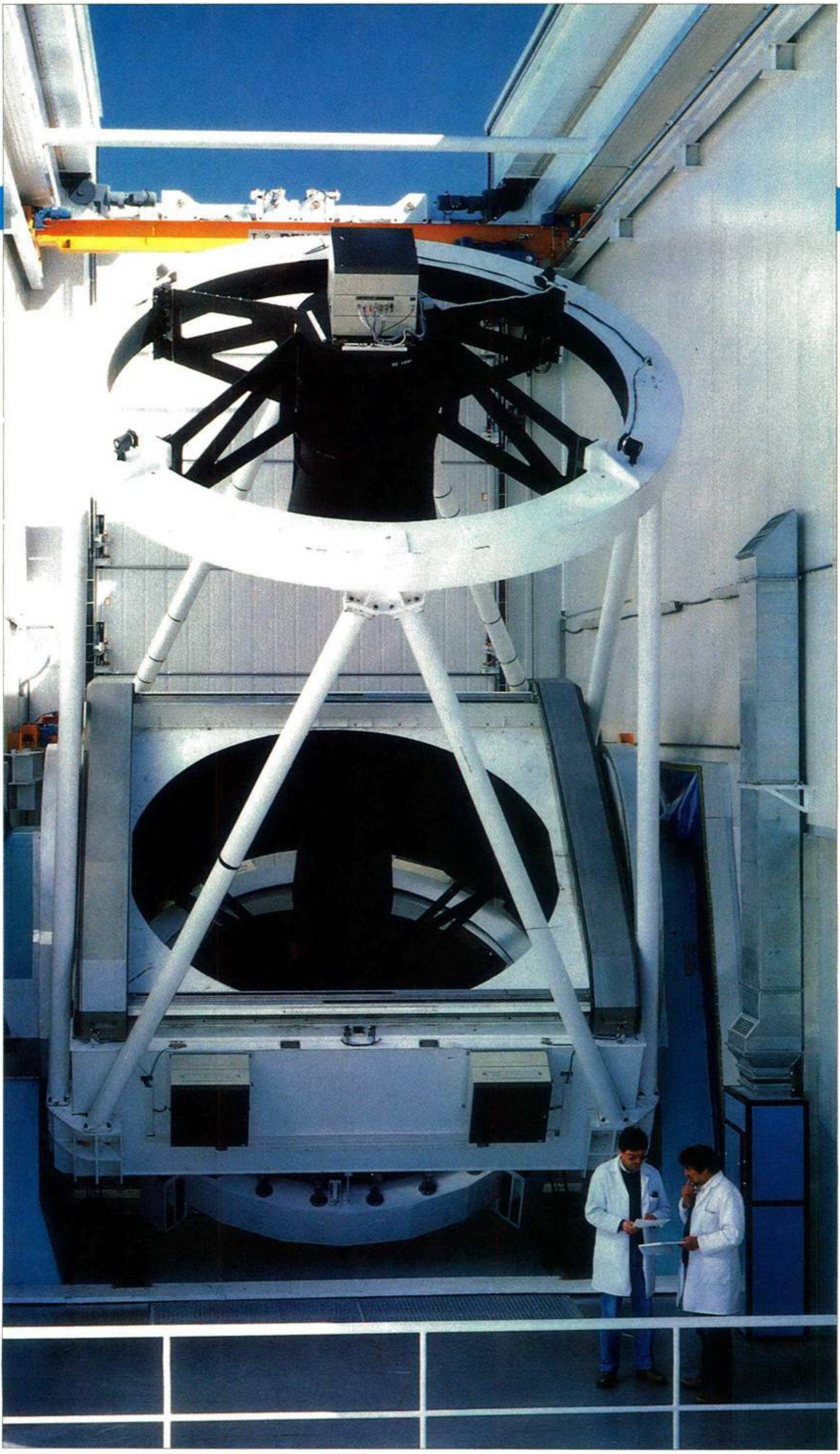
ON THE COVER: The Orion Nebula, M42, never fails to astound even the most seasoned observers. For more about the celestial sights of Orion, see page 78. Photo by Jack Newton using a 25-inch f/5 Newtonian.



THE NEW TECHNOLOGY TELESCOPE is the first in a series of supertelescopes for the 1990s. Photo courtesy the European Southern Observatory.

ASTRONOMY®

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Behind the Scenes

OF TELESCOPES — ON THE GROUND AND IN ORBIT

There are more large ground-based telescopes under consideration or under construction today than ever before. In this issue of ASTRONOMY, we examine the instruments that within the decade will reach back in time to show us the galaxies forming.

Leading the pack is the 10-meter Keck telescope. Perched atop Mauna Kea on the island of Hawaii, the Keck was scheduled for first light in late September. Of the really big telescopes, the most ambitious is the European Southern Observatory's Very Large Telescope, with a design so radically different that it could not have been attempted before the present decade. Four enormous 8-meter telescopes act in computer-driven concert to form images with the light-gathering power of a single 16-meter monster. Our story on these giants and other giants-to-be begins on page 34.

But the future is already here, at least in part. The 3.5-meter New Technology Telescope foreshadows the efficient, high-performance telescopes of the 1990s. Its computer-optimized optics in a thermally-controlled rotating telescope building make the NTT the sharpest telescope on the Planet. Writer Joel Harris visited the NTT in the high Andes mountains this spring; his story about "the future that is now" begins on page 44.

For another important telescope — the *Hubble Space Telescope* — the future is looking better. In spite of images seven times larger than expected, *Hubble* has begun to do real astronomy. ASTRONOMY reports *Hubble's* first scientific results in the AstroNews story beginning on page 22.

But the issue remains: how much will *Hubble's* fat images affect its performance? We asked the people charged with operating the telescope — astronomers at the Space Telescope Science Institute — to report on the current status of HST. Their report, couched in admittedly technical jargon, begins on page 30.

It is pointless to gnash our teeth and pull our hair over the errors that cripples *Hubble*; the best response is to accept the facts as they are and make new plans. America has an operational telescope in orbit, we have instruments aboard it that can still make valuable astronomical observations, and we have astronomers eager to observe — so let's stop whining and put *Hubble* to work!

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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Letters

The Trouble with Hubble

What's wrong with America? What's wrong with NASA? What has happened to good old-fashioned credibility and accountability?

Man was not meant to utilize space — it is a hostile environment and ill-suited to manmade ventures. I think we should put the money earmarked for such foolish projects into helping people here on Earth, and chalk up the space program to a bitter lesson of history. — *Daniel W. Bricker, St. Petersburg, Florida*

I feel sick. A week after the "unbelievable" double star image from *Hubble* was first published, we learned in small print that the telescope had spherical aberration. After reading this I saw an ad in your magazine for a $49.95 computer program that "puts the universe at your fingertips." I guess the only difference between the $50 and NASA's expenditure of $1.5 billion is the agency's miraculous ability to pull the wool over the innocent taxpayers' eyes. — *Jacquin Kahn, Jacksonville, Florida*

— These two letters typify dozens we received expressing much the same feelings of shock and outrage. Yet while we're all disappointed with HST's *flawed primary mirror, it's important to recall that other ultimately successful missions (most notably* Voyager*) have been afflicted with "disasters" of a similar magnitude. And, time and again, spacecraft engineers have shown extraordinary inventiveness in working around problems and in salvaging remarkable amounts of science from "hopeless" situations. Is* HST *a write-off? No way — for example, just see the lead story in AstroNews (page 22).*

The Brightening Planetarium Sky

With light pollution becoming a bigger problem each day, it seems that discussions among amateur astronomers always include some mention of the problem. It seems like there is no solution that does not involve an extremely large public education program aimed at the end users of lighting. Unless the public at large makes its feelings known to lawmakers and lighting designers, we will lose the beauty of the night sky forever.

During a recent conversation with Leon Knott, director of our city's Settlemyer Planetarium, I hit on what seems to be an ideal way to drive the point home to everyone who attends a planetarium show.

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Over the past few years many companies have jumped on the "Plössl" bandwagon. Some sell "house-brands," while others have added an element to impress you, calling the eyepieces Plössls even though the design resembles an Erfle. Ten years ago, Tele Vue Plössls were designed for sheer performance, not maximum marketing advantage.

Sure, imitators and "house-brands" come close to Tele Vue, but they haven't quite made the grade yet. Tele Vue Plössls still deliver the sharpest fields edge to edge with the least amount of lateral color. Plus, we now include a rubber eyeguard with every model, and maintain our 100% full field inspection process at f/4. Consistency is so good, you'll never have a problem buying pairs for binocular instruments.

So don't settle for "house-brands" or imitations, especially when the performance of Tele Vue Plössls is available at spectacular savings.

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Most shows mimic ideal sky conditions — that is, no clouds and no light pollution. Many people who see the show are impressed and later go outside to see the real sky, only to be let down by vast amounts of local light pollution. Usually these people are lost forever to astronomy because they haven't been told the whole story. They don't know that a dark site is required to see the sky well. I think astronomers are missing a great opportunity to tell the rest of the story.

Every planetarium show should end with a short explanation that the sky appears dark from a dark site, followed by a demonstration of what they can expect to see with various degrees of light pollution. This could be followed with questions and answers, and even handouts.

At present this method offers the most direct route to public opinion. By increasing awareness we can change lighting so that it competently does its job of lighting roadways and sidewalks without ruining the night sky. — *Phillip J. Loss, Rock Hill, South Carolina*

What about the Optics?

I was really excited about your article "Astronomy Tests Four Refractors" by Robert Burnham (June 1990) until I read it. Burnham wrote barely six paragraphs concerning optical performance compared to twenty-one paragraphs about the mounts. I feel that optical performance is the major consideration when comparing refractors, not the mountings. I am going to buy one of these four, but the article didn't clarify which is best for me. Why didn't he rate the telescopes' performances on planets with each other, like concluding which instrument gave the sharpest views of Jupiter? — *Gene Bordelon, Sherwood, Arkansas*

— The attention we paid to mountings was a result of our experience with the four telescopes. Optically, all of them were excellent. Therefore the mountings made the biggest differences in how usable the telescopes were.

While we did conduct actual field tests with the instruments, variability of weather and seeing prevented us from drawing clear-cut conclusions from them alone. (The optical tests were done indoors with an artificial star under controlled conditions.)

However, in answer to your question (sort of), all the instruments gave equally outstanding views of Jupiter — although they naturally differed slightly due to the instruments' various focal lengths. This is why we stressed that given the telescopes' across-the-board optical excellence, we felt that one's final choice would depend mainly on matters such as f/ratio, portability, and mounting stability.

Coming Out of the Closet

I thoroughly enjoyed Philip M. Bagnall's article "Are You a Closet Astronomer?" (Viewpoints, August issue). My experiences with my favorite hobby were the same but I was never a closet astronomer. I began to study astronomy 25 years ago at the age of 14, when the subject was nowhere near as popular as it is today. Two of my schoolfriends also became amateur astronomers and we competed to gain as much astronomical knowledge as possible. I remember being regarded as an eccentric, which was accentuated by a local paper doing a story on me. (I wonder how Mr. Bagnall would have reacted to this!)

Years later I applied for a job as a telephone engineer, knowing I was underqualified. As a result, the interview went terribly until the interviewer asked about my hobbies. He must have reasoned that if I was able to apply myself to a reasonably technical hobby like amateur astronomy then I should be a capable telephone engineer. I got the job. Soon thereafter I held an observing session by wandering down the town's deserted streets along with a friend and a pair of binoculars. A police car soon pulled up and the occupants were ready to arrest us. Some information about the Moon and planets allayed their suspicions.

Now that astronomy is so much more popular I don't feel like an eccentric, but I occasionally find eyebrows raised when I make mention of my hobbies. I've lost count of the times I've been asked whether I believe in UFOs, life on other planets, or other off-beat topics. If out of all the people who ask me such things in jest, I can find one who is genuinely interested, I feel lucky. Then I can introduce the newcomer to the stars, and I feel like I've done my part for astronomy. — *Ken Clark, Wallasey, Merseyside, England*

You *Can* Buy a $200 Telescope

I'm somewhat amused by the current debate over whether or not amateurs can purchase a quality telescope for $200. I started out several years ago with a pair of 7x35 binoculars until I came across a "telescope for sale" sign on a bulletin board at the local community

AN OWNER'S VIEW:

Genesis™

Photo by Tom Orzechowski

DEAR MR. NAGLER,

Several years ago, I purchased a 10" Schmidt-Cassegrain telescope. On this new instrument, I carefully compared the performance of the most respected brands of eyepieces before concluding that the **Tele Vue** Plössls were giving me the best views. Along with 4 of your Plössls (55, 26, 17 and 13mm) and your 2.5x Barlow, I bought a Giant Off-Axis Guider, which I frequently use as a telecompressor. Although I have always been pleased with your eyepieces, there are limits to just how much a long-focal-length telescope can be telecompressed! ■

For over three years, I have wanted a second instrument for rich-field observing and photographing. Although your **Renaissance** is most impressive, it just wasn't quite the instrument I wanted and the **Oracle** was a bit too small. Then came **Genesis.** Knowing what a stickler you are for details in both design and production, plus my total satisfaction with your eyepieces; sight unseen, I bought a **Genesis** based solely on those facts and your ads in the magazines. ■

I took delivery of my **Genesis** at the Texas Astronomical Society's meeting on 7/22/88. Even with all the light pollution in that North Dallas parking lot, my new **Tele Vue** 32mm Wide Field eyepiece, at less than 16x, clearly resolved Saturn's rings as separate from the disc. When a friend asked to try his 12 mm Nagler-II with his 3x Barlow, I knew I had bought a "winner." The Cassini Division was as sharply defined as I have ever seen it plus the surface and ring detail was second only to a view I once saw under a Texas Star Party's dark skies through a nearly $20,000, 10.7" f/15 Maksutov! ■

The reason for this letter is simple. I have now had my first opportunity to take my new **Genesis** out to the T.A.S.'s dark-sky observing site (100 miles north of Dallas). In short order, the **Genesis** had attracted a group of experienced observers (most holding full Messier Certificates) away from their larger telescopes. Simply, **Genesis** stole the show! Except for an occasional comparison view, my 10" Schmidt-Cassegrain sat idle because I was seeing far greater clarity and detail with my new **Genesis.** Although I had with me a full set of filters (Deep Sky, U.H.C., O-III and H-β), none were ever used. ■

While I had anticipated a gorgeously resplendent Double Cluster, it was truly more dazzling than I expected. But, some real surprises lay ahead. Take M-33 in Triangulum: 4" just isn't enough aperture for such a diffuse spiral, right? WRONG! With the 32mm Wide Field, I was seeing tremendous detail in a galaxy over 1/3 the width of the field. I could write paragraphs describing a California Nebula covering half the field plus all the glorious sights through Sagittarius and Scorpius like the Lagoon, Trifid and M-21 all in the same field; or, four gleaming globulars, M-22 & 28 with NGC-6638 & 6642. ■

While the Great Andromeda Galaxy (M-31) spread across more than 2/3 of the field, we were all alternating time at the eyepiece, trying to see who could count the most dust lanes. It was more beautiful than even the photographs from the leading observatories. I have never seen M-110 appear as large relative to M-31. One observer even held his hand in front of the eyepiece and suggested that we try observing a projected image! While that may have been beyond even **Genesis'** capability, it does prove we were looking at no dim M-31. There was a debate over which eyepiece provided the better view: the 13mm Nagler's greater contrast and detail or the 32mm Wide Field's greater coverage. Each outperformed the other in its own way and both provided splendid views. ■

All night, comments from seasoned observers included a thesaurus-full of one word expletives of praise, wonder and astonishment. While glued to the eyepiece, other comments included: "... but this is ONLY a 4-inch" to "Boy! You sure made no mistake in buying this one" and "Oh, No!... How am I ever going to make my wife see the need?". One observer even yelled to a friend across the field, "Get over here if you want to see what Rich Field is SUPPOSED to look like." Personally, I can hardly wait to start taking astrophotos with it. ■

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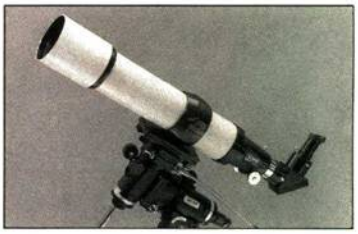

It would have been impolite of me not to write and tell you just how much of a Big Bang your **Genesis** telescope has already created in my deep sky observing. ■

Appreciatively yours,

Kent G. Ledlow

Kent E. Ledlow

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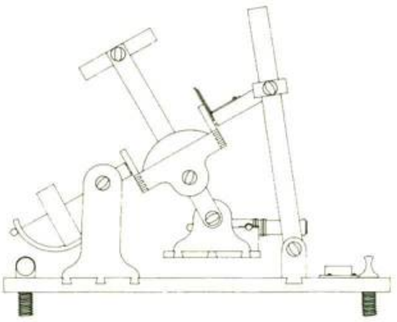

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college. For $175 I bought a used Criterion 6-inch reflector, four eyepieces, and a clock-driven mount. If you look in the right places, you certainly can buy a good telescope for $200. — *Michael Crivello, Santee, California*

One Tip for Improving Your TV

I enjoyed "Ten Tips for Improving Your Telescope" by Alister Ling (August 1990). Ling's analogy comparing lack of contrast in a telescope to a snowy TV picture (implying poor signal-to-noise ratio) is reasonably valid, but his recommendations for correcting the problem in the TV is wrong. A better antenna will help the problem, and so might a better set — but the coaxial cable makes little difference. — *Paul H. Bock, Jr., Hamilton, Virginia*

Spectacular Aurorae

On Saturday, July 28, 1990, I was with approximately 100 teenagers and their adult advisors on a camping experience in the mountains 50 miles southeast of Salt Lake City, Utah. As darkness fell I saw the remote glow of Salt Lake City in the distance and also a fairly strong glow that was much larger to the northeast. The Moon had just set and produced a small glow in the northwest. Because the only thing within 100 miles to the northeast was the High Uintah Mountains wilderness area, I knew we had a spectacular auroral show in the making.

I called my 17-year-old son out of the games to come and see. Soon more than fifty people were watching, as the lights continued to brighten and change in shape. At one point a distinct vertical band of light about 2° wide arced upward and nearly touched Polaris. Throughout 30 to 45 minutes we watched shifting patterns of bands under Cassiopeia, some as wide as 5° or 6°. The maximum height of the show was approximately 40° or 45°. An hour after I first noticed it, the show had diminished and we went to sleep. It was one of the most inspiring observational experiences I've had and I know it created a bunch of interested skygazers who had never before viewed a dark sky. — *Raeburn G. Kennard, Salt Lake City, Utah* □

ASTRONOMY welcomes comments, suggestions, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

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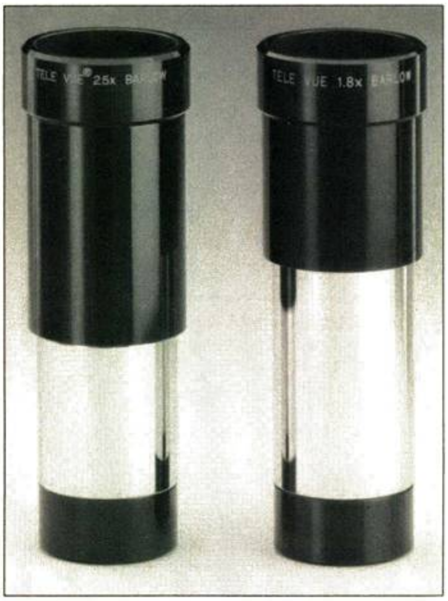

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WHERE I THINK AMATEUR ASTRONOMY IS GOING

by Tom Mote

The Viewpoints round-table discussion in the September issue ("Where is Amateur Astronomy Going?") sparked some thoughts in me, and I'd like to make a few comments from behind a pair of 65-year-old eyes.

Several participants mentioned that potential amateur astronomers, especially the younger ones, are being discouraged by the complexity and expense of the equipment seen in advertisements and at star parties and gatherings. First of all, it's up to us — the active amateurs and probable role models — to make a much greater effort to show that amateur astronomy can be enjoyed at many levels of effort, affluence, and technical sophistication.

Second, I have noted a most unfortunate tendency among our children and grandchildren to expect that they will arrive at adulthood with all the niceties that their parents spent years achieving. Finally, just as no one would expect to begin student pilot training in the cockpit of a 747, it is equally foolish to enter amateur astronomy by spending many thousands of dollars on equipment — even if you have the means to do so. We, our media, and our dealers are going to have to start cooperating in an effort to help newcomers make *prudent* equipment choices.

In an exchange regarding kids, Alan Dyer made a number of cogent comments. But while I agree with him that much depends on teachers, I think it's important to recognize that teachers have been pushed into a corner. Teachers, good or bad, are subject to being fired if they deviate from the approved curriculum and texts. And more and more, special interest groups are trying to narrow the range of views in the texts. To assure widest sales, publishers respond by dumbing down the books' content, and the result is a public school science curriculum that is inadequate.

After more than 25 years as a college and university science professor I am very pessimistic about the drop in quality of preparation among incoming students. I have taught a non-laboratory intro astronomy course for several years and can tell you that it fills up faster than any other course I teach. A typical class section has one honors student taking the course out of intellectual curiosity, three or four science majors who have just finished one of my statistics courses, and about 30 liberal arts students taking the course because it has no labs and still fulfills their science requirement. Let me tell you, the abysmal scientific training and sheer lack of interest in those liberal arts students is startling. I salvage a few each year but I'm convinced that we — collectively, the country's amateur astronomers — need to capture these kids' imaginations much, much earlier, long before middle school and high school apathy sets in.

Lastly, I want to respond to the rather lengthy discussion on the emergence of CCD technology in the hobby. I respect Dave Eicher's ideas and experience, but I have to take issue with his suggestion that one can truly observe only in real time and only without electronic assistance. I have felt the cold wind in my face while flying in an open cockpit and I have heard the argument that flying in a nice warm, closed cabin isn't really flying at all. I've done both kinds of flying, and I have greatly enjoyed both.

> **We must not give newcomers the idea that any one facet of astronomy is "the" center of it all.**

What's most important, I think, is to avoid giving newcomers the impression that one facet or another of our hobby is somehow "the" center of it all. Let me give you an example. I have been a ham radio enthusiast since I was a small boy and have been a licensed operator for more than 40 years. For longer than I can remember, there has been a rancorous battle in amateur radio over the question of proficiency in Morse code. Those who continue to demand it have the upper hand and Morse proficiency is still required — despite the fact that we now have far more efficient means of digital communications.

It's clear to me that, at this point, the *code requirement serves* mainly as a barrier to enlisting new hams into the hobby. In your round-table Greg Swan noted that the average age of the ASTRON-

OMY reader is 41.8 years, a figure that has gone up 5.5 years in the last 5 years. The average age of licensed hams is now in the high 60s. (At 65, I'm one of the kids!) Let's be very careful not to shut the gates to amateur astronomy in a way similar to what amateur radio has done to itself.

Maybe because the participants were all fairly young, one aspect of CCDs wasn't ever mentioned: it can help people like myself continue active observing. As an 18-year-old aviation cadet I had 20/15 visual acuity and a dark adaptation potential that was incredible. By the time I retired from the Air Force, I had collected a pair of glasses but still had pretty good eyesight. Time, however, has marched on and I find that I cannot, even when fully dark-adapted, see nearly as much through a telescope as can younger observers under identical conditions.

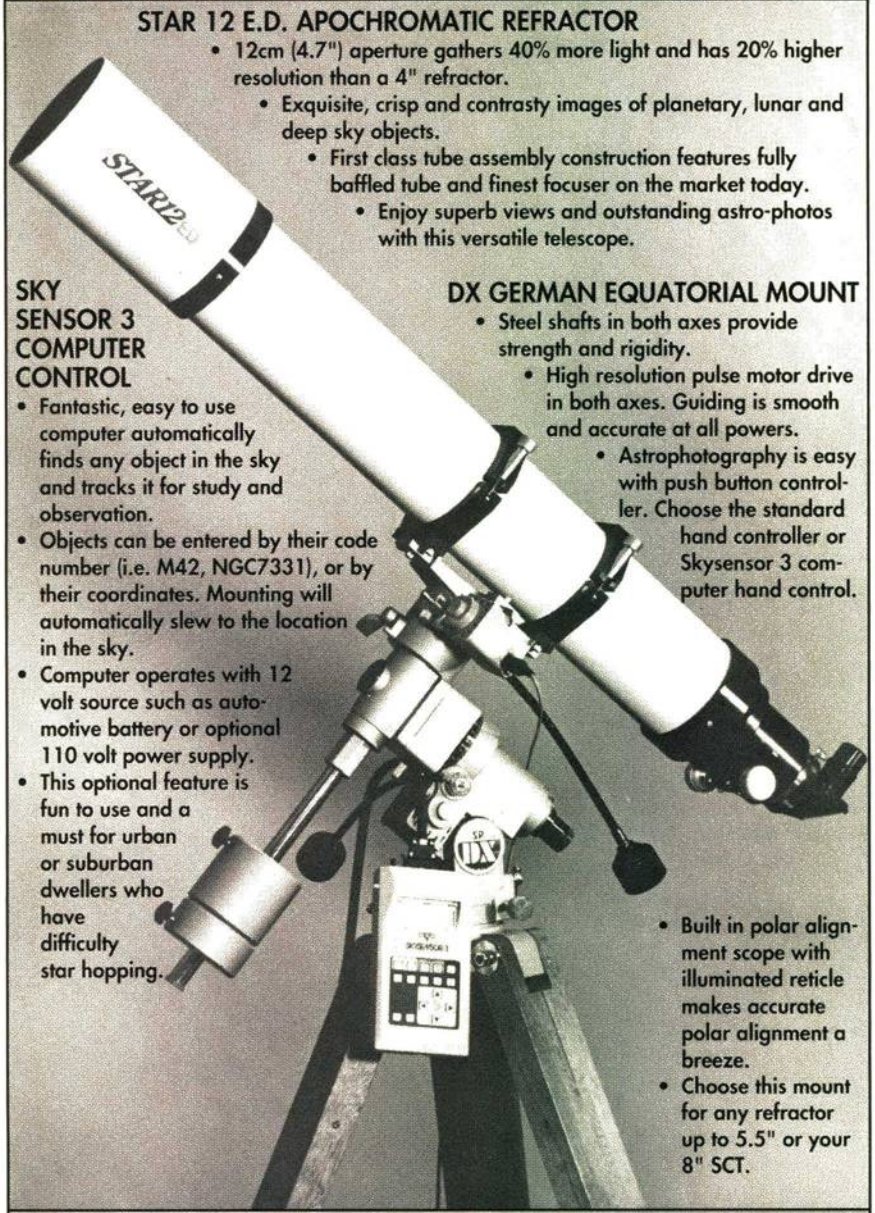
Six years ago I began a series of binocular vs. monocular vision experiments and found that, particularly in older observers, random retinal noise becomes far less noticeable when using binocular telescopes. However, the expense in money and complexity can be discouraging. A binocular eyepiece attachment is not very effective for the deep-sky observer, and I really don't want to think about the problems involved in creating a "double C11." (I can't even get very serious about a double C8.)

So what's to do? Well, I think I'm going to delay my second retirement a couple of years more and use part of the additional income to get one of the CCDs mentioned in the September issue. I also have my eye on one of those 4-inchers written up in the June issue. My thinking is that I could piggyback the 4-incher on my C11 and use the CCD on one telescope for wide-field viewing and swap it to the other for narrow views. A 4-incher also means that when I go to a good star party, I can leave the "gut-buster" at home and just enjoy the dark skies.

ASTRO TALKS TO BRIAN MARSDEN

Dr. Brian Marsden is head of the Central Bureau for Astronomical Telegrams in Cambridge, Massachusetts. He is best known as the final arbiter on the names given to newly discovered comets. He spoke with Robert Reeves.

My interest in astronomy goes back to the age of five when I came home from school in Cambridge, England,



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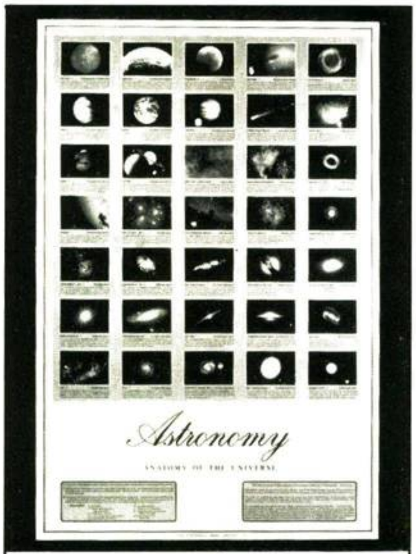

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and found my mother in the backyard watching an eclipse. I took the subject up more seriously around the age of 11. In addition to reading about it, I spent a lot of time trying to predict eclipses and the positions of the planets, preparing my own almanacs and writing about astronomy in a magazine I prepared for my own amusement. Then I got into the British Astronomical Association. Its Computing Section publishes an annual astronomical handbook and soon had me hard at work calculating ephemerides of comets and predictions of occultations of one of Jupiter's satellites by another.

In those days, of course, I did things by logarithms, and it was quite an extravagance for a schoolboy such as I to spend a pound or more on some seven-figure log tables. With the ubiquitous pocket calculator, not to mention personal computers, younger generations find this sort of thing hard to believe, but mechanical calculators used to cost more than £1,000 and were hardly household appliances.

Later I was able to get a mechanical calculator on loan from the BAA. By then I was studying mathematics at Oxford University. The Royal Greenwich Observatory had a fine summer program for university students. Most students were attached to the observational and astrophysical departments. There was some reluctance at having students in the Nautical Almanac Office, but in 1957 I became the first such student in seven years.

It was largely because of the summer program that I came to the United States. I wanted to work in the "old-fashioned" area of celestial mechanics and there was not much interest in this subject in England in 1959. Sir Richard Woolley, the Astronomer Royal at the time, as well as Donald Sadler, who ran the Nautical Almanac Office, recommended that I go to Yale.

At the time, Yale was the acknowledged center for celestial mechanics and Dirk Brouwer the international leader in the field. *Sputnik 1* had gone up a year or two earlier, and although many still regarded celestial mechanics as belonging to the astronomical stone age, Brouwer appreciated that it was pivotal to the space age. Enormous amounts of money were available and Brouwer was able to build up a thriving research center. I have always regarded it as a great privilege to have been in on that.

At Yale, calculating machines ran by electricity! More significant, however, was the IBM 650 computer. Within a few days of my arrival I had programmed it to compute preliminary orbits of comets and I believe I was the first person actually to apply such a program and publish the result for a new comet. Although comets were my main interest, I wanted a good grounding in all areas of celestial mechanics, so for a dissertation I decided to work on the orbits of Jupiter's Galilean satellites.

Those were heady days. The rapid development of the electronic computer meant that one could obtain highly accurate representations of all orbital problems, but general orbital theories are also of interest. Looking back after 25 years, I'm surprised that we are still pretty well stuck with the planetary orbit theories done by Simon Newcomb almost a century ago!

After Yale, I took up Fred Whipple's offer of a position at the Smithsonian Astrophysical Observatory (SAO) in Cambridge, Massachusetts. I felt that more intensive work on cometary orbits was needed There was concern at the time about the influence of nongravitational forces on them — for example, that gas sublimating from the comet could alter its orbit. Although Whipple had considered these forces in his icy-conglomerate comet model in 1950, there was some doubt about whether they existed at all.

To check it was necessary to make more rigorous gravitational computations. After it became clear that nongravitational effects were the rule rather than the exception, I incorporated some additional terms in the equations of motion. This then permitted us to solve for some nongravitational parameters by integrating additional variant orbits. Computations like these require an enormous database of positional observations. I spent literally months going through old journals with observations extending well back into the 19th century and putting the data on punched cards.

While at Yale I used an IBM 7090 computer to run the orbits of seven lost comets up to the present. These comets had all failed to show up for several decades. It wasn't clear whether the observations had been inadequate, the computations had been incorrect, or if the comets had been destroyed. As a result of my computations, Elizabeth Roemer picked up one of the objects, periodic Comet Holmes in 1964. By 1967, P/de Vico-Swift and P/Tempel 1 had been *recovered* as well. I had considered the project would be a success if only one of the comets were recovered — and we had three of them! The

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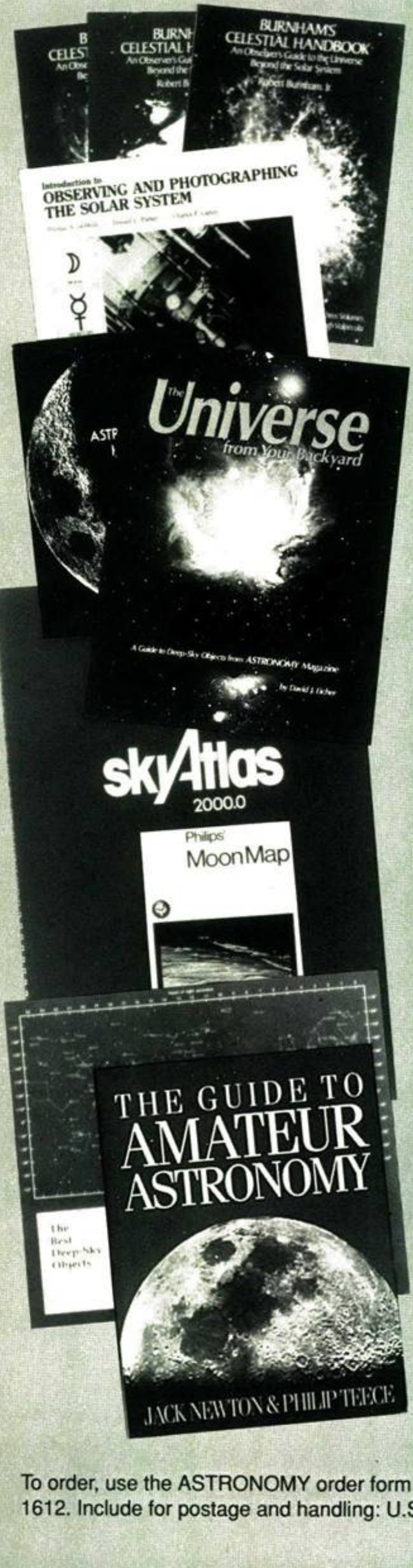
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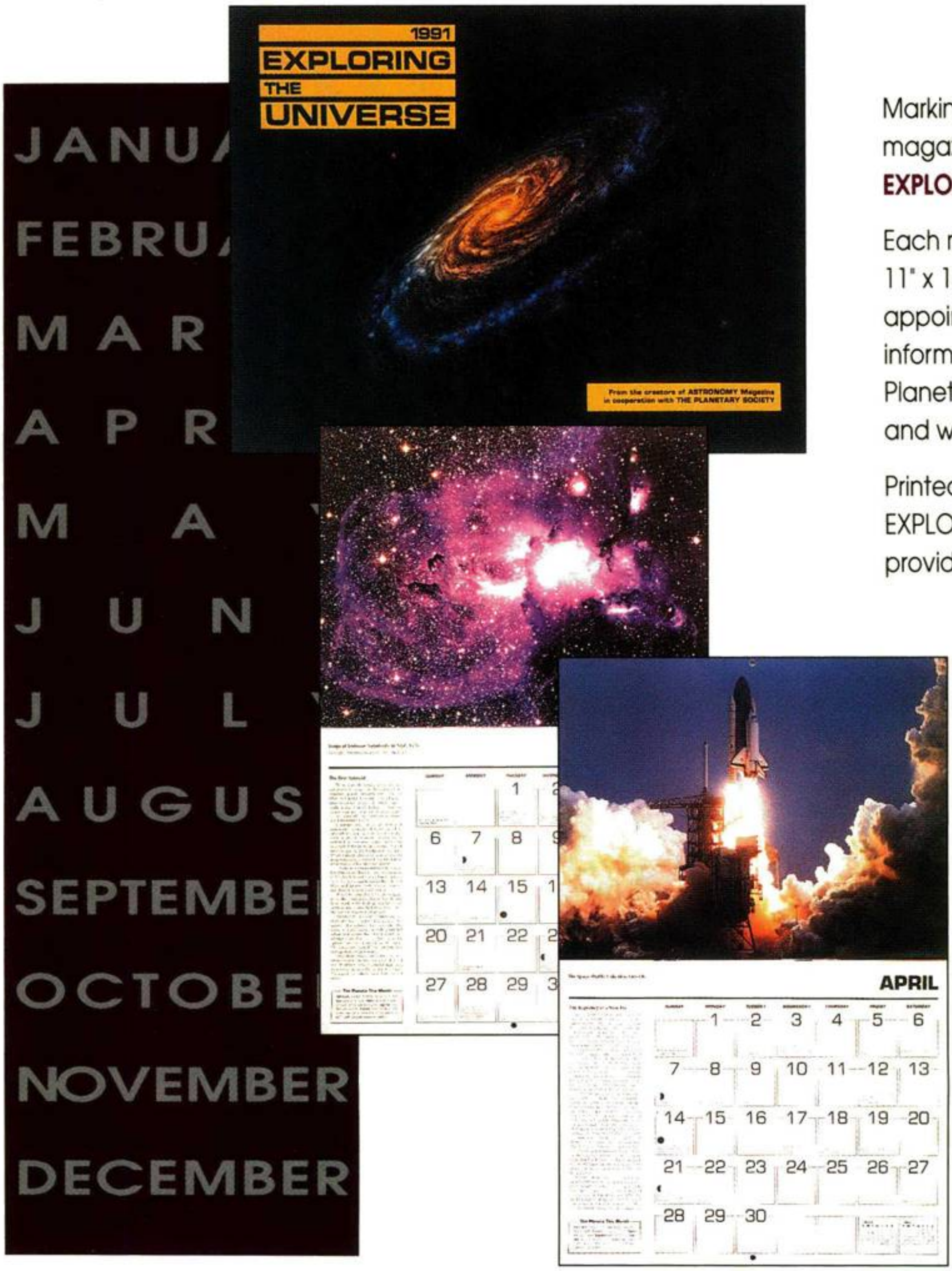
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remaining four comets have still failed to appear and presumably were destroyed.

The International Astronomical Union's Central Telegram Bureau moved from Copenhagen to the SAO at the beginning of 1965, some nine months before I joined the staff. Owen Gingerich was then running the Bureau, but he found it took too much away from his studies on the history of astronomy. He passed it on to me at the beginning of 1968 and I have been doing it ever since.

The telegram bureau can take quite a bit of time. In the early days I was pretty much doing it alone. I typed the IAU *Circulars* on an old IBM Selectric typewriter in the office. When we got a new Selectric in the office, I took the old one home so I could prepare the *Circulars* in either place. Initially the telegrams were all handled in SAO's communications center. When the center wanted to cut their hours and close on weekends, I had to get into the telegraphic business myself. I got a TWX teletype machine for the office, as well as another one with the same number at home so that I could always receive and transmit messages.

Running the telegram bureau made it difficult for me to go away to astronomical meetings, on vacation, and such. Dan Green came to work for us in the summer of 1978, and now he is the bureau's associate director and actually puts out more *Circulars* than I do.

The amount of time spent on the telegram bureau varies a lot. One extreme was Comet Ikeya-Seki, which was around in 1965 at just the time I started at SAO. Gingerich felt he lost a whole month to this comet! On the other hand, there were only 39 *Circulars* during the whole of the following year.

Other busy times were associated with Comet Bennett in 1970, Comet Kohoutek in 1973, and Nova Cygni in 1975. Halley's Comet was really not a problem because the interest was spread over such a long time, starting with the first recovery attempts as early as 1977.

Our single most troublesome time involved Comet IRAS-Araki-Alcock in the spring of 1983. As soon as we had the initial discoveries collected we realized that it was going to pass only 0.03 AU from Earth *one week later*. I knew immediately it would be a week of hell. The printed *Circulars* were just not getting delivered in time, and Dan and I were swamped with continuous phone calls. There must have been at least a thousand of them. The only thing that worked were the telegrams and telexes, but only a small fraction of the *Circular* subscribers get them.

The obvious thing was to have some kind of electronic distribution, but E-mail, modems, and personal computers were then quite a bit more primitive than now. I felt the easiest thing for us was to put the *Circulars* in a special directory in SAO's computer and then have people dial up by modem to see them. Early in 1984, I decided to set up this system for a monthly charge of $9. There were 20 subscribers immediately. By early 1987 this number had doubled.

Then came Supernova 1987A. By good fortune this coincided with the time we got on to the SPAN computer network, and the number of subscribers immediately increased by a factor of three. Since mid-1988 we have also been sending the *Circulars* out by E-mail. We did not do this earlier because E-mail was often unreliable, with a lot of the E-mail messages seeming to drop into black holes.

Once you discover a comet, we tend to trust that your next discovery report is correct — but sometimes it isn't!

Another publication we issue is the *Minor Planet Circulars*. In 1978, Paul Herget retired as director of the Minor Planet Center in Cincinnati. I was asked to take it over and we moved it to Cambridge.

Herget used to produce the *Minor Planet Circulars* about twice a year. I decided to do them monthly, figuring that there would perhaps be about 20 pages in each batch. Almost immediately the amount of activity began to increase, and the total work of the Minor Planet Center has gone up by a factor of eight or ten since we started. Every batch this year has contained more than 160 pages. Much of the work is the result of amateur activity in Japan, Italy, England, and Germany.

People sometimes ask us how long we wait until deciding that someone should have sole credit for a comet discovery. It's usually quite straightforward. We don't accept additional claims after the announcement has gone out! That means the comet is adequately confirmed and precludes the possibility of fraud. Sometimes discovery messages get delayed. In such cases we have to make a judgement, trying

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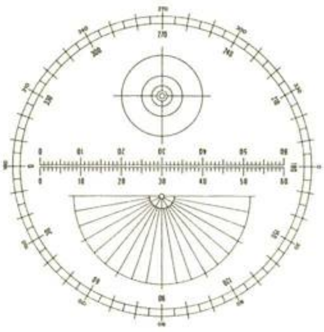

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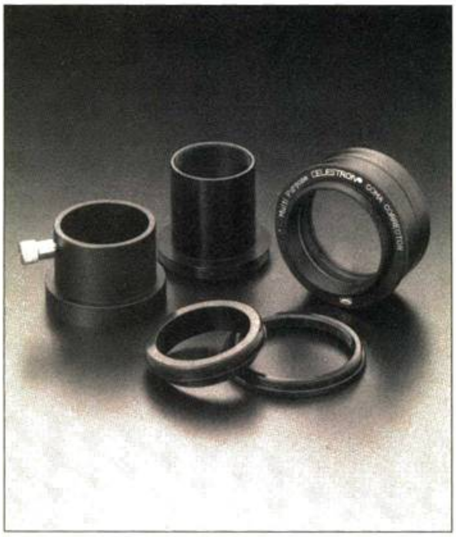

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One can almost always tell when someone has a real discovery. We receive many vague reports from inexperienced amateurs who think they have a comet on a single photograph, or they can see a fuzzy thing in the vicinity of a bright star. I usually dismiss these automatically. If there is something there, it will almost certainly also be found independently by a more experienced observer.

We like to receive reports by E-mail or telex/telegram. Phone calls are discouraged, especially in the middle of the night. I have never received a useful call in the middle of the night, and callers usually get some rude comments from my wife.

The Selectric typewriters went by the wayside and were replaced by computers and daisy-wheel printers in 1982. Since 1988 the *Circulars* have been neatly and expeditiously prepared on a laser printer. In 1988 the TWX machines went too, and Western Union just has an open line to one of our MicroVAX computers. This is a little sad. In the old days you really knew some great discovery might be on the way when the TWX rattled into action! Now the computer just gives a little beep.

Some people think we've been a little severe with our requirements on the discoverers of minor planets. Long ago, it was sufficient simply to send in a single rough position. Now we insist that discoverers provide observations on two different nights. This enables us to come up with obvious and many not-so-obvious identifications. We also try to inform the discoverer whether further observations are needed. Ideally, they should get observations on two more nights later in the dark run, giving an orbital arc of ten days or more. With these longer arcs there are more possibilities for finding identifications. With observations at three or four different oppositions, really good orbits can be computed. Such minor planets aren't going to be lost in the future, and they can be given permanent numbers.

It is a common misconception that to guarantee the discovery of a minor planet all you need to do is to get measurements on three consecutive nights. Such solutions might work out for fast-moving objects near Earth, but they are absolutely useless for the vast majority of minor planets out in the main belt. Attempts at general solutions usually give completely meaningless results.

Although it took 53 years to double the number of permanently numbered minor planets from 1024 to 2048, the next doubling took less than 12 years. It seems likely that there will be yet another doubling in a comparable time, with #8192 being assigned before the end of the century. What is driving this? Well, there's clearly more interest in the subject than ever before and many planetary astronomers agree that it is the minor planets and the comets that tell us most about the origin and evolution of the solar system.

Several observers are in the process of abandoning their traditional photographic astrometric programs in favor of CCDs. The availability of improved, larger CCD chips and the space telescope's *Guide Star Catalogue* has enabled this to be done with the venerable 61-inch reflector that SAO operates at the Oak Ridge Observatory in Massachusetts. For bright objects enough reference stars can sometimes be recorded in only 1 second, and a full astrometric reduction from a dozen reference stars can be achieved within 15 minutes. Shorter exposures mean that more objects can be observed and Oak Ridge productivity has increased tenfold. About 30 percent of the minor planets get permanent numbers solely because of follow-up observations by Oak Ridge at subsequent oppositions.

We are also involved with the *Hubble Space Telescope*. We will be notified whenever a moving object is discovered, and then we will advise whether it is worthwhile for *HST* to make further observations or if the follow-up observations should be made elsewhere — or whether the discovery is so ordinary that it can be ignored.

Once people who are searching for comets, novae, etc., are successful, they enter a new plane. Actually, it is a dangerous plane, because with one discovery under your belt we tend to think that the next time you report something you've done it right. I think the only erroneous comets given designations while I have been running the Central Bureau are cases where the discoverers had previously found real comets.

Some would doubtless criticize me for my rather cavalier dismissal of unconfirmed discoveries — whether by professionals or by amateurs. There's always the fringe that wonders how many great discoveries get lost because "the establishment" doesn't take them seriously. But it rarely works out that way. If there *really is* anything of consequence, it will almost always show from data carefully produced by those with the appropriate experience and competence. ☐

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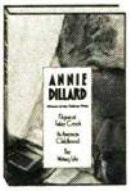
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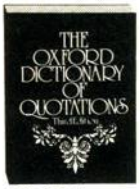
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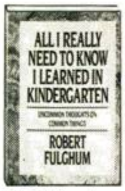
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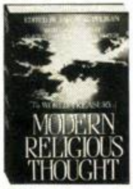
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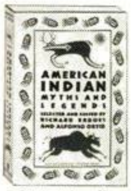
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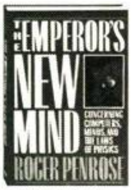
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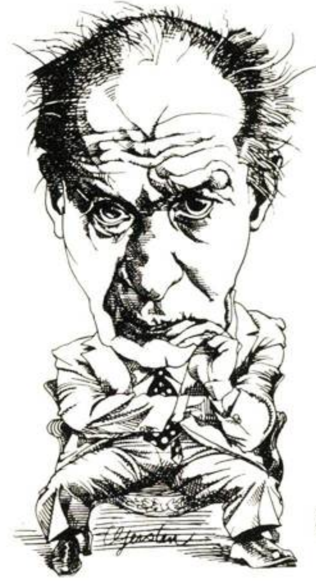

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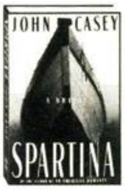
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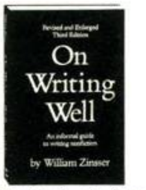
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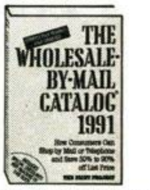
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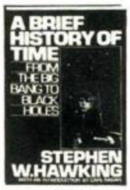
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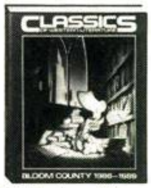
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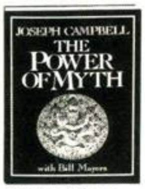
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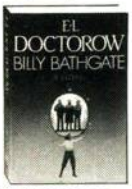
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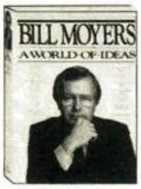
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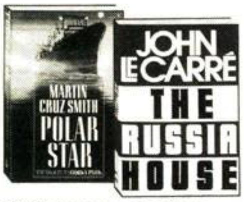
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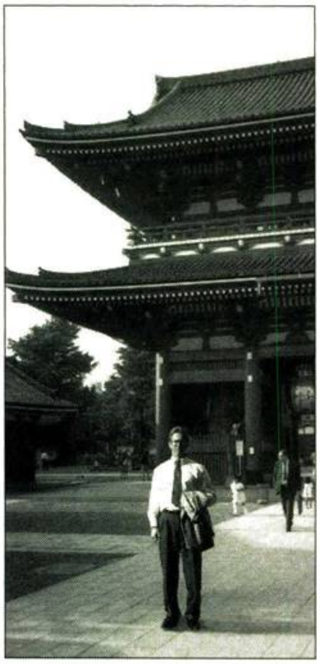

Orion® 80mm Wide Field Refractor

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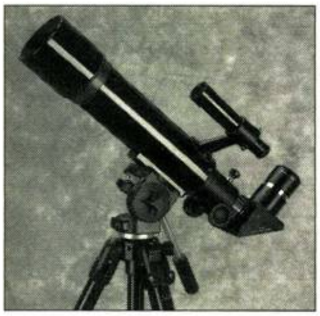


Orion's hottest new addition is this 80mm f/6.25 Super-ED Achromat refractor! One of Japan's most famous lens makers designed this 2-element optical system with high performance ED glass. You get performance approaching competitive models selling for over twice the price! Ultra-flexible, it's a great choice for both wide field and higher power observation. Superbly crafted rack-and-pinion focuser accepts 1.25" or optional 2" accessories. With achromatic finder scope, 1/4-20 tripod mounting block. Diagonal/eyepieces not included. Tripod mount optional.

#9080 **$449** (6.77)

Orion® Big Eye 8x50 & 11x80 Finder Scopes

NEW!

Ideal for upgrading any telescope including Schmidt-Cassegrains. Available non-illuminated or with wireless, adjustable, battery-operated illuminated reticle and Polaris grid for accurate polar alignment. With 90° diagonal prisms. Optional deluxe dual-ring brackets are perfect for 8" and 10" Celestron or Meade; will fit many others, too.

8x50 Models

The 50mm objectives gather 2.7 times more light than 30mm finders!

8x50 Standard Finder #7100	**$89.95**	(3.31)
8x50 Illuminated Finder #7135	**$134.95**	(3.56)
Bracket— For 8" & 10" #5143	**$25.95**	(1.89)

11x80 Models

These huge finders gulp in over 7 times the light of 30mm finders; 2.5 times more than 50mm models! You might spend more time viewing through the finder than through your main telescope!

11x80 Standard Finder #7146	**$219**	(4.16)
11x80 Illuminated Finder #7143	**$269**	(4.16)
Bracket— For 8" & 10" #5140	**$37.95**	(2.39)

America's #1 Source For Major Brands!

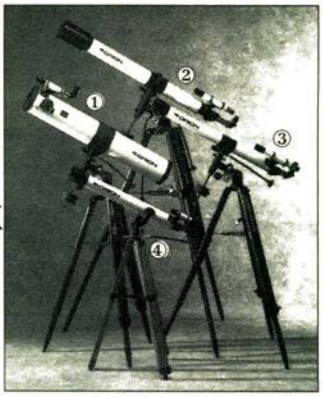
CELESTRON

Meade

Tele Vue

Edmund Scientific

2 NEW MODELS!



❶ Orion® 4.5" Equatorial Reflector

NEW!

Our new 4.5" f/8 reflector gathers 3.6 times more light than 60mm telescopes; twice as much as 80mm models; ideal for deep space observation. Full featured equatorial mount with slow motion controls & setting circles. Achromatic 6x30 right angle finder and two eyepieces: 25mm (36x) and 9mm (100x). Deluxe hardwood tripod and accessory tray. Compare our price!

#9097 **$399** (18.73)

❷ Orion® 80mm Deluxe Equatorial Refractor

NEW!

With 77% more light gathering power than 60mm models, our 80mm f/15 is perfect for planetary and lunar observation. Heavy duty equatorial mount with slow motion controls & setting circles. Loaded with accessories: two eyepieces, 25mm (36x) and 9mm (100x), 2x Barlow Lens, terrestrial Erecting Prism, achromatic 6x30 Finder Scope, Sun Projection Screen, Moon Filter, and star diagonal prism. Deluxe hardwood tripod and lighted accessory tray. Compare our price!

#9098 **$499** (19.43)

❸ Orion Sky Explorer 60mm Equatorial Refractor

The Sky Explorer's sturdy equatorial mounting is designed specifically for astronomy; it's ideal for lunar and planetary study, while providing good views of nebulas, star clusters, and double stars. By day, it's a powerful terrestrial telescope, great for nature study and scanning distant vistas.

It features a 900mm focal length, MgFl2 coated objective lens; 6x30 achromatic crosshair finderscope; rack-and-pinion focuser, fully coated right-angle star diagonal prism; two quality fully coated Kellner eyepieces, 25mm (36x) and 9mm (100x); all metal equatorial mounting; worm gear slow-motion control knobs; celestial coordinate setting circles; dual flexible control cables; adjustable counterweight; adjustable deluxe hardwood tripod; and lighted accessory tray.

#9092 **$329** (12.70)

❹ Orion TeleVista 60mm Altazimuth Refractor

This affordable telescope is equally at home viewing the rings of Saturn or boats across the bay. One of our most popular sellers, it will provide you with years of enjoyment viewing celestial and earthly delights. It includes a quality coated 2-element achromatic objective lens and two quality Kellner .965" eyepieces, 25mm & 9mm, for sharp, clear images at 28x and 78x. Sturdy all metal optical tube and yoke mount, plus strong adjustable wooden tripod, smooth focuser and diagonal prism. A great, economical choice for observers of all ages.

#9091 **$169** (9.90)

Orion® 7x50 Observer™ Binoculars

NEW!

Our new Observer binocular is an ideal moderately priced night-vision binocular for both astronomy and general purpose daytime observation. Fully coated optics with a 7° field of view, and a bright 7mm exit pupil. Rugged ribbed rubber covering for a good grip.

#9620 **$84.95** (3.66)

Superior Performance 7x50 Adlerblick Binoculars

Incredible wide field eyepiece design, fully multi-coated BAK-4 prisms and best special glass objective lenses make the 7x50 Adlerblick the the archrival of European brand binoculars selling for 3-4 times the price. Orion buys direct, saving you money. Includes deluxe hard case, lens caps, straps.

#9612 **$269** (4.16)

Orion® Enhanced™ Giant Binoculars

20% more light transmission than ordinary "fully coated" binoculars. Fully Multi-Coated optics and superior BAK-4 prisms provide fantastic contrast and greatly improved edge sharpness.

11x80 MC- Brightest, widest field available. Ideal for deep-space observation under dark skies. Hand-holdable.

#9502 **$349** (6.43)

16x80 MC-45% higher power, excellent for astronomy and daytime observation. Tripod recommended.

#9496 **$379** (6.43)

20x80 MC- Highest power model perfect for smaller deep-space objects and long range daytime views. Tripod required.

#9498 **$389** (6.43)

Orion® 10x70 Enhanced Giant Binoculars

Big binocular performance in a lightweight package you can hand-hold for hours. Ideal for sweeping the dust lanes of the Milky Way. Fully Multi-Coated, BAK-4 Prisms. Fantastic!

#9501 **$279** (5.87)

Orion® Little Giant™ 9x63 Roof Prism Binoculars

Popular mid-sized binocular, fully multi-coated and remarkably light weight. Excellent contrast and sharpness at center of field, although edge sharpness is not as good as our porro-prism binoculars. 5.5° field of view. Weight: 2.8 lbs.

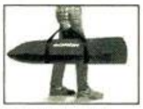
#9500 **$199** (4.80)

Deluxe Eyepiece Case

Organize and protect your valuable eyepieces and other accessories. This durable case with double hinges holds up to 10 eyepieces plus barlow. Die cut foam insert for snug secure fit. O.D. 8-1/2"x12-1/2"x3-1/8".

#5913 **$17.95** (2.49)

Deluxe Field Tripod Tote Bag



Designed for the field tripod with padded insert to separate wedge from tripod during transportation. Specifically made for wedge combinations of Schmidt-Cassegrain telescopes up to 10" aperture. Allows storage without changing polar alignment. This blue bag is made of tear, rip and mildew resistant 100% Cordura nylon.

#15096 **$79.95** (4.65)

Orion® VariPower™ 2-3x Multi-Coated Barlow Lens

Our best barlow offers significant improvement over other models we've seen. The magnification is adjusted by sliding the internal lens cell along a calibrated scale (you don't have to poke a finger or pencil inside to do this). Fully Multi-Coated optics provide excellent sharpness, contrast and brightness. 1.25" diameter.

#8748 **$69.95** (2.59)

Orion® 3-element Fully Multi-Coated Barlow Lens

Fully Multi-Coated 3-Element Barlow lens provides superior imaging with precise color correction at three wavelengths. For maximum light transmission and highest contrast, we have used the finest quality multi-coating on each air to glass surface. 1.25" diameter.

#8750 **$59.95** (2.59)

Orion® Deluxe Fully-Baffled Multi-Coated Barlow Lens

Fully internally opaqued and baffled to block stray light for noticeably higher contrast. Large 27mm multi-coated 2-element lens provides 2x magnification with any 1.25" eyepiece.

#8746 **$49.95** (2.39)

Orion® Sky Explorer™ Mini Deep Sky 8x56 Binoculars

56mm objective lenses gather over 2.5x the light of ordinary 7x35 binoculars. Perfect for viewing faint celestial objects, daytime viewing. Best Multi-Coated BAK-4 optics. 6° field of view.

#9504 **$139** (4.16)

100% Satisfaction
Money-Back Guarantee
If you are not completely satisfied with your purchase from Orion, for any reason, just return it in new condition within 30 days after delivery for a full refund.

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High Resolution Orion® Ultrascopic Eyepieces

Unlike other premium eyepieces, Orion Ultrascopics offer complete multi-layer coatings on ALL surfaces, for superior light transmission and contrast. Modern 5- and 7- element designs for pinpoint star images and breathtaking detail. Wide 52° field of view. Compare with other brands selling for much more!

Wide Field 5-element

35mm #8560 **$89.95** (2.59)

30mm #8562 **$79.95** (2.59)

25mm #8564 **$64.95** (2.59)

Medium-High Power 5-element
20mm #8566, 15mm #8568, 10mm #8570, 7.5mm #8572

$59.95 ea. (2.59)

High-Power 7-element 5mm #8574, 3.8mm #8576

$79.95 ea. (2.59)

Orion® MegaVista™ 1.25" Wide Angle Eyepieces

Incredible fully multi-coated high-transmission 7-element eyepieces with integral rubber eyeguard and long eye-relief.

10.5mm- An incredible 67° field for outstanding planetary or deep space performance.

#8552 **$109** (2.79)

16.8mm- Outstanding high-contrast eyepiece with stunning 70° field ideal for deep space.

#8554 **$119** (2.79)

Orion® UltraZoom™ 7-21mm 1.25" Eyepiece

The finest zoom you can buy for your 1.25" telescope. An excellent choice for astronomy or terrestrial observing. 65°-35° field.

#8556 **$129** (2.79)

Orion® Explorer Series 1.25" Eyepieces

Remarkably affordable, Multi-Coated parfocal eyepieces with great performance. Each carefully selected series has been chosen to provide a sensible progression of magnifications. Threaded for filters. Internally blackened to prevent stray light reflections.

Kellner Eyepieces-
6mm #8536, 9mm #8538, 12mm #8540, 18mm #8508, 25mm #8510, 40mm #8512

$33.95 ea. (2.19)

Orthoscopic Eyepieces- 5mm #8500, 7mm #8502, 9mm #8504, 12.5mm #8506, 18mm #8524, 25mm #8526

$46.95 ea. (2.19)

Orion® Explorer Series .965" Eyepieces

Get the most from your small telescope with these fine multi-coated eyepieces. Standard .965" barrels fit all Japanese standard small telescopes.

.965" Orthoscopic Eyepieces-
5mm #8580, 7mm #8581
9mm #8582, 12.5mm #8583

$37.95 ea. (2.19)

.965" Kellner Eyepieces
18mm #8584, 25mm #8585
.965" Achromatic Huygenian Eyepieces- 40mm #8586

$24.95 ea. (2.11)

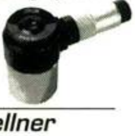
World's Finest Illuminated Reticle Eyepiece

6mm Orthoscopic design for required high-power guiding, plus unique X-Y adjustable reticle positioning for easy guide-star alignment. Wireless LED illuminator has adjustable brightness.

#8487 **$139** (2.79)

Orion® 9mm Orthoscopic Illuminated Reticle Eyepiece

9mm Orthoscopic eyepiece with wireless adjustable brightness illuminator. Bull's-eye within three concentric circles helps measure limits of acceptable guiding error.



#8488 **$119** (2.79)

Orion® 12mm Kellner Illuminated Reticle Eyepiece

12mm Kellner eyepiece with cable plugs into LX/3, LX/5 and Premier drive bases, and most drive correctors with illuminated reticle output for polar alignment and guiding.

#8482 **$69.95** (2.59)

77° Field UltraScan Wide-Angle Eyepieces

NEW!

Unlimited visibility is yours with up to 77 degrees of field to catch your eye. High quality optical materials and superb coatings, for the ultimate in contrast and resolution.

1.25" UltraScan Eyepieces
Five optical elements utilizing the latest high refractive-index optical glass materials achieve extremely wide fields with fewer elements than many competitive eyepieces, reducing weight and cost. Each lens surface is fully Multi-Coated, for the ultimate in contrast and elimination of stray reflections. Integral rubber eyeguards.

9mm #8420 **$99** (2.79), ***12mm*** #8421 **$109** (2.79)

15mm #8422 **$129** (2.79), ***19mm*** #8423 **$139** (2.79)

2" UltraScan Eyepieces
These incredible oculars provide breathtaking panoramic, bright views that will astonish you!

30mm 2" UltraScan Eyepiece - This 5-element, 77 degree field UltraScan eyepiece combines the widest possible apparent and true fields with a larger image scale than our 40mm.

#8424 **$199** (2.79)

40mm 2" UltraScan Eyepiece - Orion's brightest, widest true-field UltraScan eyepiece utilizes a sophisticated 7-element design, providing a 68 degree apparent field, the widest we could fit into the 2" diameter barrel.

#8425 **$179** (2.79)

Orion® SkyGlow™ Enhanced Light Pollution Filters

Enhance your viewing of faint deep sky objects with the best broadband light pollution filter you can buy. Our SkyGlow absorbs frequencies emitted by city lights, allowing transmission of the rest of the visible spectrum, yielding dramatic results.

SkyGlow Broadband Filters-
For use in slight to moderately light polluted areas.

1.25" Broadband Filter-fits 1.25" eyepieces.

#5660 **$59.95** (2.59)

Schmidt-Cassegrain Broadband Filter- fits rear cell of Meade & Celestron SC scopes.

#5658 **$79.95** (2.59)

52mm Broadband Filter-
fits all camera T-rings.

#5668 **$66.50** (2.59)

SkyGlow UltraBlock Filters- For severely light polluted areas.

1.25" UltraBlock Filter-
fits 1.25" eyepieces.

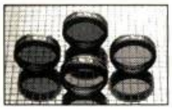
#5654 **$79.50** (2.59)

Schmidt-Cassegrain UltraBlock Filter- fits rear cell of Meade & Celestron SC scopes.

#5656 **$99.00** (2.59)

Orion® Color Filters for Eyepieces

Solar system observations are dramatically improved by Orion colored filters. For visual use, thread one into the barrel of any standard eyepiece. For planetary and lunar photography, Schmidt-Cassegrain owners can attach the filter to the eyepiece inside the tele-extender. Can also be threaded directly into a universal camera adapter.



Basic Set of 4 Filters .965"- Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5510 **$29.95** (2.19)

Basic Set of 4 Filters 1.25"- Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5514 **$39.95** (2.19)

Expansion Set of 4 Filters 1.25"- Includes #21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.

#5516 **$39.95** (2.19)

Deluxe Set of 8 Filters 1.25"- Includes all the filters in our basic and expansion filter sets.

#5517 **$74.95** (2.79)

Individual 1.25" Filters- #80A Blue (#11040), #58 Green (#5540), #25 Red (#5536), #15 Yellow (#5532), #21 Orange (#5534), #47 Violet (#5538), #11 Light Yellow-Green (#5530), #82A Very Pale Blue (#5544)

$11.95 ea. (1.89)

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

.965" #5664 **$14.95** (2.11)

1.25" #5662 **$14.95** (2.11)

Popular Observer's Chairs

Make observing more comfortable and enjoyable with one of these great chairs.

Standard Model-
Has adjustable-height center column and padded vinyl seat. Folds for easy storage.

#5935 **$37.95** (3.96)

Deluxe Model-
Is much heavier-duty, built for professional musicians. Extra thick padding, wide footprint. Adjustable and disassembles for storage.

#5934 **$89.95** (6.53)

Breakthrough Low-Price Plössl Eyepieces!

NEW!

These new Multi-Coated Plössl eyepieces are incredibly low priced! Good quality optics for sharp, clear images. Precision four-element Plössl lens elements mounted in sturdy aluminum barrels. Available in 12mm, 18mm, or 25mm focal lengths, with 1.25" barrels. Buy all three for less than some single eyepieces!

12mm-#8596
18mm-#8597
25mm-#8598

$39.95 ea. (2.39)

Orion FlexiShield™ Dew Caps

NEW!

Eliminate dew problems with FlexiShield! Better performance, more rugged, and easier storage than rigid dew caps. Made of durable, unbreakable, fire-retardant Kydex™. Form into a tube with the velcro closure, or change into a flat rectangle or small-diameter tube for easy storage and transportation. No paint to chip or scratch off. They fit your telescope tube snugly, thanks to the wide rubber padding and full-length velcro closure. Nothing needs to be attached to your telescope; needs no screws, no tape, no glue. Once in place, they are very rigid and do not block the optical path. Models to fit most telescopes.

90mm Celestron/Meade Spotting Scopes	#4203	**$24.95** (2.39)
90mm Celestron Rubber Armored Spotting Scopes	#4205	**$24.95** (2.39)
4" Meade Schmidt-Cassegrain	#4204	**$24.95** (2.39)
8" Celestron/Meade Schmidt Cassegrains	#4200	**$39.95** (2.39)
10" Meade Schmidt Cassegrains	#4201	**$49.95** (2.39)
11" Celestron Schmidt Cassegrains	#4202	**$59.95** (2.39)

Orion® Dew Zapper

Orion's Dew Zapper is a sure-fire cure for dew problems on your 8" or 10" Celestron or Meade Schmidt-Cassegrain telescope. Dew Zapper gently replaces lost heat, bringing the corrector plate temperature slightly above air temperature.

8" Dew Zappers-fit all Meade & Celestron 8" Schmidt-Cassegrains

DC Model #3503, AC Model #3504 **$39.95** (2.39)

10" Dew Zappers- fit all Meade 10" Schmidt-Cassegrains

DC Model #3506, AC Model #3508 **$39.95** (2.39)

Dew Remover Gun

Moisture that interferes with viewing dissipates quickly with this 12V DC, 156 watt warm air gun. Has 4-1/2' cord.

#5601 **$17.95** (2.48)

Starlite Red LED Flashlight

The Starlite is the only adjustable-brightness night-vision red flashlight. Lifetime solid-state LED can't burn out. Extra efficient electronic circuit for long battery life. Uses one 9-volt battery (not included).

#5714 **$24.95** (2.11)

Astronomer's Flashlight

Indispensable and indestructible. Has special night-vision red filter and a diffusion lens for even illumination. An essential addition to your astronomy accessories. Requires 2 D-cell batteries (not included).

#5701 **$9.95** (1.89)

Rechargeable Battery Porta-Pack

12 Amp Hour Porta Pac
Ideal for operating your telescope plus higher power-consuming accessories such as an Orion Dew Zapper. Battery is encased in high-impact polystyrene. Carrying case of Cordura nylon with shoulder strap and handle. Wt. 10 lbs.

#2354 **$99 ea.** (6.23)

Orion® Dual Balance System

Unlike ordinary counter-weights, our system allows instant adjustment in both directions. Easily balances your scope to offset both piggyback loads or rear-cell cameras, 2" diagonals, and other accessories. Rigid, precision machined dovetail bar mounts to telescope in existing accessory holes.

For Meade SC 8"	#5150	**$74.95** (4.65)
For Celestron 8" C-8	#5149	**$79.95** (4.65)
For Meade SC 10"	#5152	**$84.95** (4.65)

Orion® T-Adapter

For prime focus photography. Use with T-ring to match your 35mm camera. For Meade, Celestron 8", 10" SC.

#5116 **$27.95** (2.39)

Orion® UltraGuider

NEW!

Our newest off-axis guider for Celestron and Meade Schmidt-Cassegrain scopes. Easily adjustable prism allows wider choice of guide stars. Heavy no-flex construction. Precision helical focuser for your guiding eyepiece. Adjustable camera focal plane position. Suitable for advanced deep-space astrophotography. Compare our price!

#5169 **$119** (2.79)

Standard Off-Axis Guider
Name brand quality at a low Orion price! Our popular, precision anodized guider with fully coated prism.

#5144 **$59.95** (2.59)

Rack & Pinion Focusers

NEW!

Perfect for telescope makers or upgrading existing telescopes. These top quality focusers are designed specifically for Newtonian reflectors. Chrome plated brass & black enamel finish. Two sizes to fit your needs. Fit any size tubes.

1.25" Focuser
Quality diagonal-cut rack for smooth focusing. Secure slide-fit eyepiece holder. Integral socket for single-stalk diagonal support if desired. Knurled focus knobs.

#13017 **$44.95** (2.39)

2" & 1.25" Focuser
Large clear diameter ideal for larger scopes and wide-field optics. Massive oversized knurled knobs for easy fine focusing. Precision diagonal cut rack. Long travel for both visual and photographic use. Interchangeable 2" and 1.25" holders with set screws.

#13019 **$69.95** (3.31)

Orion® 45-Degree Erect Image Diagonals

NEW!

See the world as it really is with Orion's new 45-degree erect image diagonal. Upside-down, backwards and topsy-turvy images can often confuse even the stoutest and most experienced observer. Turn it right-side-up with your choice of three models to select from.

.965 Diagonal #8759 **$59.50** (2.59)

1-1/4" Diagonal #8753 **$59.50** (2.59)

Size-Adapting Hybrid Diagonal #8755 **$59.50** (2.59)

Star Diagonals

1.25" Star Diagonal
Primarily for astronomical use, lets you view at a right angle. Multi-coated, for 1.25" eyepieces.

#8763 **$39.95** (2.39)

.965" Star Diagonal
Same as 1.25" Star Diagonal, but with standard coated optics. Works with .965" eyepieces and eyepiece holders.

#8761 **$24.95** (1.89)

2" Star Diagonal

Get the widest possible field of view from your Schmidt-Cassegrain Telescope. This star diagonal features a special aluminized and overcoated precision first-surface flat mirror.

#8767 **$89.95** (2.89)

Orion® Tele-Extenders

For high powered photography with your Meade, Celestron 8", 10" Schmidt-Cassegrain

Standard Tele-Extender
Use this Tele-Extender in conjunction with an eyepiece. Attaches to visual back of Meade or Celestron Schmidt-Cassegrain telescopes, and to 35mm camera with T-ring, sold separately.

#5125 **$27.95** (2.39)

Variable Tele-Extender
Uses an adjustable extension tube, allowing magnification to be changed without switching eyepieces. Thumbscrews lock extension tube securely in place. Attaches to 35mm camera with T-ring, sold separately.

#5127 **$39.95** (2.39)

Universal Camera Adapters

Standard Universal Camera Adapters
Combination Eyepiece Projection Tube and Prime Focus Adapter for refractors and reflectors with 1.25" eyepiece holders. Use with T-Ring (sold separately) to match your 35mm camera.

.965" #5268 **$29.95** (2.39)

1.25" #5264 **$34.95** (2.39)

Variable Power Camera Adapter

Unique sliding barrel design allows variable projection distances during eyepiece projection photography, eliminating the need to change eyepieces when magnification changes are required.

#5262 **$44.95** (2.39)

America's #1 Source for Telescopes and Binoculars

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- Shipping & handling charge for UPS Ground or U.S. Mail to lower 48 states only are listed in (parentheses) after each price.
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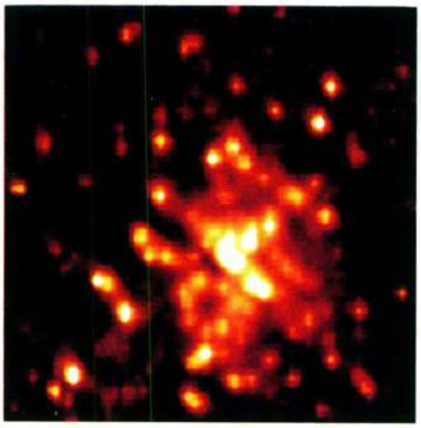
FIRST SCIENCE FROM HST

Flawed mirror notwithstanding, the *Hubble Space Telescope* made a scientific breakthrough during an engineering test — and did it with the instrument most adversely affected by the defective optics. Moreover, the results, even in their raw, barely-processed state, far surpass those taken with ground-based telescopes.

Using *HST's* wide-field/planetary camera, NASA's astronomers focused the giant telescope on the star cluster known as R136 in 30 Doradus, the Tarantula Nebula in the Large Magellanic Cloud, which is seen in the direction of the southern constellation, the Goldfish. The R136 cluster is an enigmatic object that has long puzzled astronomers. As recently as a decade ago, it was thought to be just a single extremely massive star, and even the best current ground-based images show only a handful of stars in the cluster.

HST's new photo is especially important because it reveals that the central arcsecond of R136 contains more than 60 stars. The telescope made the image in violet light, so the stars recorded are primarily very large, luminous, and hot O-type stars. Astronomers estimate that many of them weigh as much as 100 suns each. To put R136's numbers into perspective, it's as if roughly a hundred hot, young, massive stars were crammed into a volume of space no larger than from the Sun to Alpha Centauri, 4.3 light-years away.



DOZENS AND DOZENS OF STARS crowd into the central region of the cluster R136 in the constellation of Doradus. This new *Hubble Space Telescope* image reveals details never seen from the ground.

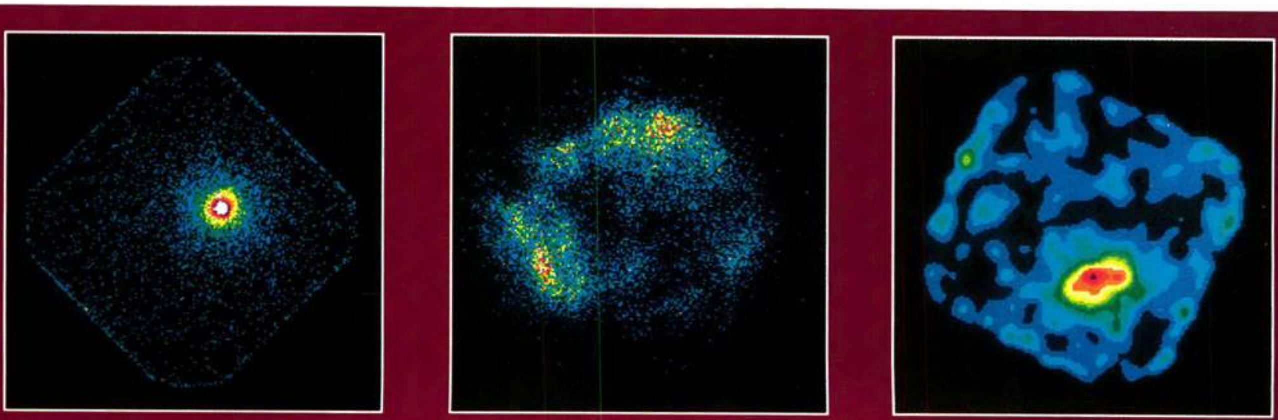
The new observation by *HST* worked around the flawed mirror's characteristics, which are such that stars are easy to resolve although extended sources like nebulae are not. Therefore, while the R136 cluster lies deep within a diffuse hydrogen nebula, none of the gas is evident in the images. Astronomers now intend to process the image further to reveal all the stars that can be detected. Next they will measure the star brightnesses in several color bands. Their goal will be to understand much better the internal workings of this compact, but highly massive young cluster.

A STORMY DAY ON VENUS

While planetary scientists look forward to the unveiling of Venus by *Magellan's* radar scans, some data from the 12-year old *Pioneer Venus Orbiter* is giving us a look at Venus' weather. NASA researcher Christopher Russell has concluded that Venus has lightning. This has long been suspected, but it was thought that the Venusian lightning was caused by volcanic activity. Russell, however, reports that the lightning appears to be sparked by conventional thunderstorm activity.

Writing in the Dutch journal, *Space Science Review*, Russell said that analysis of the *Pioneer* radio signal data shows as much, if not more, lightning within the thick, high cloud layers of Venus as there is on Earth. Unlike Earth's atmosphere, Venus' thick cloud deck is some 35 miles above the planet. There, temperatures are close to freezing, and atmospheric pressure and cloud movements are similar to Earth's lower atmosphere.

Though Venus has a very slow rotation rate (one Venusian day equals 243 Earth days), Venus' clouds race around the planet once every four Earth days. Therefore, clouds pass through the



ROSAT, an orbiting x-ray telescope built by West Germany, Great Britain, and the United States, was recently launched by NASA (see story on page 28). The first pictures from its High Resolution Imager show (above, left to right) the compact binary star system Cygnus X-2, the Cassiopeia A supernova remnant, and the Abell 2256 cluster of galaxies. In the Cas A image, the broken "ring" reveals x-rays from an expanding plasma shell at several million degrees' temperature. The emission in the Abell cluster comes from hot gas swept out of the galaxies in the cluster and compressed between them. Smithsonian Astrophysical Observatory photos.

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planet's day and night sides over roughly the same times periods as do clouds on Earth. Russell's analysis shows that Venus' thunderstorms seem to occur mostly in the Venusian afternoon and at dusk. A similar pattern of afternoon heat build-up creates thunderstorm activity here on Earth.

While some unknown instability in Venus' ionosphere might produce the observed radio signals, Russell said, "We know of no phenomenon with regular occurrence in local planet time even remotely like what we see. No other known property of the ionosphere varies in this way. All the evidence points to a source in the Venus clouds."

MISSED US BY THAT *MUCH*

On July 10, the Earth had a close encounter with a maverick asteroid. Called 1990 MF, this chunk of rock wizzed by at 22,000 miles an hour, passing only 3 million miles from Earth. This was among the closest approaches of any asteroid in the last 50 years. By planetary standards, 1990 MF is an insignificant bit of debris, perhaps only 300 to 1,000 feet across. Of course, had it hit the Earth, the consequences would have been far from insignificant.

1990 MF came close enough that astronomers at the Arecibo Radio Observatory were also able to bounce radar signals off the tiny object. This gave a measure of the asteroid's orbit: 1990 MF orbits the Sun every 28 months in a path that takes it just beyond the orbit of Mars.

This latest discovery joins the growing family of known Apollo asteroids, those whose orbits cross the Earth's. Many of these Apollo asteroids, including the latest find, have been discovered by the Palomar Planet-Crossing Asteroid Survey (PCAS). Headed by astronomer Eleanor Helin, the PCAS astronomers use the 18-inch Schmidt camera on Palomar Mountain to scour the skies for errant asteroids. They've become very skilled at hunting down Earth-crossers — 1990 MF is PCAS's fourth such discovery this year alone. Their total count since starting the hunt in 1973 is now 39 near-Earth asteroids.

Amateur News

SUMMER MEETINGS DRAW ENTHUSIASTIC CROWDS

"This is just fantastic — a thousand crazy astronomers wandering around a mountaintop for thirty-six hours." Joel Harris, a native of Burbank, California, was describing the first Stellafane convention he had attended in over 15 years. The 55th annual Stellafane gathering took place on July 27-28, 1990, on Breezy Hill in Springfield, Vermont. More than 1,000 people from as close as Springfield itself to as distant as England stormed over the mountaintop to observe, hear talks, and simply discuss their favorite pastime. Brief rain and semi-persistent haze limited the value of observing — the exception being bright meteors and a spectacular auroral show — but the talks went on as planned.

Change was the big word at this year's Stellafane. When the great telescope designer Russell Porter and his friends founded Stellafane — meaning "shrine to the stars" — in 1926, they hosted a small group that mingled about a distinctive pink clubhouse at the rocky summit of Breezy Hill. Four years later the astronomers built a telescope on the summit. Now the hilltop is too small to accommodate the crowds, and the traditional tent talks and Saturday evening lecture have been moved into a new ampitheater at a site among the makeshift camps spread throughout the dense woods.

Four talks highlighted this year's convention. On Saturday afternoon John W. Briggs described the Group 70 project, in which California amateurs are building a 72-inch telescope using a mirror blank manufactured by Corning Glass Works in 1939. The Californians hope to complete the project within several years and consequently open the largest amateur observatory in the world.

Peter Ceravolo, associate editor of *Telescope Making* magazine, described how to recognize and achieve good performance from telescope optics. Ceravolo pointed out that factors such as central obstruction, design and construction of mountings for optics, collimation, and design of the tube assembly contribute substantially toward telescope performance. He suggested ways to improve existing telescopes so they deliver optimum images.

On Saturday evening Albert Boggess of the Space Telescope Science Institute delivered the official word on the troubles with *Hubble*, including the latest images and profiles showing the image degradation produced by the primary mirror's spherical aberration. Although the crowd already knew the story of what happened and that the telescope could not be fixed until 1993, it was not happy and wanted answers — and lots of them.

Following Boggess' apology came the main talk of the evening, an address by Arizona amateur David H. Levy, whose sixth comet discovery lay above the audience in the constellation Pegasus. Levy delivered a moving explanation of how he has devoted his life to hunting comets and popularizing amateur astronomy, and left the audience particularly pleased.

Three days later another significant gathering of amateur astronomers began in St. Louis, Missouri. ALCON '90, the annual convention of the Astronomical League and the Association of Lunar and Planetary Observers (ALPO), took place from July 31 through August 4, on the Washington University campus.

Participants listened to a wide spectrum of talks. On the first day of ALCON Robert Walker, director of the university's McDonnell Center for Space Studies, described his challenging experiences collecting meteorites in Antarctica. Stephen J. O'Meara, associate editor of *Sky & Telescope*, proposed unconventional ideas about limiting magnitudes. Milwaukee Astronomical Society members Dan Koehler and Richard Wiesen conducted a CompuServe astronomy computer forum that focused on plans to see the 1991 eclipse in Mexico and Hawaii.

Over the following days ALPO members concentrated on amateur observations of the planets. Jose Olivarez discussed the current unusual happenings in the cloud decks of Jupiter and what could be seen with backyard telescopes. ALPO director John E. Westfall described the upcoming series of mutual events between Jupiter's satellites. Don Parker's paper described the current apparition of Mars. A contribution from Julius Benton demonstrated how amateurs can draw the planet Saturn.

The convention concluded with a banquet and guest speaker John Dickel, who outlined what professional radio astronomers are doing and what they expect to discover in the Milky Way and in other galaxies. The event concluded as the 135 participants witnessed the announcement of the Robert E. Cox award. (See story on page 26.)

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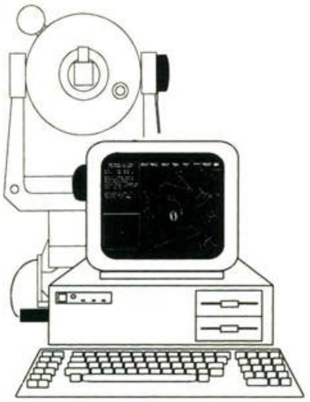

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ORANGE COUNTY ASTRONOMERS: A MODEL CLUB

It began as most astronomy club stories begin, with a few people meeting in a garage. In 1967 in Garden Grove, California, thirteen self-proclaimed skywatchers began the Orange County Astronomers (OCA), now one of the largest (550 members) and most active amateur astronomy clubs in the world. Once each month the OCA meets at a local college to hear talks by a professional or amateur astronomer, and holds two star parties at different sites, one a 20-acre desert stretch that features a 22-inch Cassegrain telescope.

As is usually the case with thriving astronomy clubs, the current situation is largely the result of extraordinary efforts by a small number of people. Byron Groves, an attorney and founding member of the club, incorporated the group in 1972. The following year the club received a grant to construct a large telescope that had been proposed by member Bob Goff, an optician at Perkin-Elmer, in 1969. Professional engineer and club member Bill Kuhn designed engineering drawings for the telescope over a three-year period before ordering construction materials. Club president Jack Child searched for several months before finding a parcel 12 miles northeast of Palomar Mountain. The telescope's optics were made by Jerry Brunache, another employee of Perkin-Elmer. The scope is a modified 22-inch classical Cassegrain with two secondaries, enabling it to be used at f/8 and f/16.

THE OCA 22-INCH SCOPE is as sophisticated as a modern observatory. Photo by John Sanford.

The OCA is active in publishing and distributing information to amateur astronomers. The club's monthly newsletter *The Sirius Astronomer* is read by over 1,000 people, and the club's sponsorship of the proceedings volumes from the Riverside Telescope Makers Conference (1979-), the Astrophoto seminars (1975-), and the Electronics Oriented Astronomy seminars (1984-), has kept all that transpired at those gatherings in the public record.

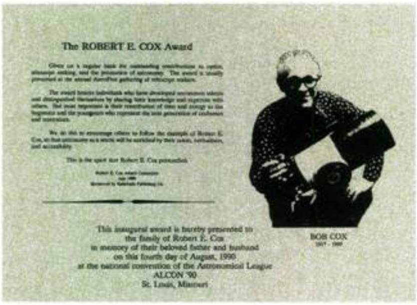
Members of the OCA recently started two new programs: Constructing a public observatory in Mile Square Park that will house an 8-inch Clark refractor, and producing and presenting planetarium shows at Tessman Planetarium at Rancho Santiago College. The shows draw audiences of 25-50 at an otherwise little-used facility. The club's outreach program provides speakers for schools and telescopes for star parties. Each year OCA members set up scopes at the Orange County Fair. Last year more than 7,000 people were given opportunities to view the Sun during the day and planets at night.

The Orange County Astronomers is an extremely active group. The members feel that although they enjoy observing, experimenting, and building, bringing astronomy to the public is their first and foremost goal. When that's the case, the members feel, an astronomy club cannot help but thrive. — *John Sanford.*

ROBERT E. COX AWARD ESTABLISHED

Four prominent amateur astronomers announced the establishment of an award to honor the memory of telescope maker and amateur astronomer Robert E. Cox, who died in December 1989 (see AstroNews, March 1990). The inaugural award was presented to the family of the late Mr. Cox at the closing banquet of ALCON '90. The announcement of the award was made earlier at ALCON '90, the national convention of the Astronomical League, held in St. Louis from August 1 through 4. Committee members are John Allseits, Daniel Troiani, Thane Bopp, and Richard Berry.

Committee member Allseits said of Cox, "Bob was an extraordinary individual. This award has been formulated by a group of his friends who feel that his enthusiasm for astronomy should be remembered." Allseits stated that the committee will seek candidates for future awards from the astronomical community.



The ROBERT E. COX Award

This inaugural award is hereby presented to
the family of Robert E. Cox
in memory of their beloved father and husband
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at the national convention of the Astronomical League
ALCON '90
St. Louis, Missouri

BOB COX

THE ROBERT E. COX AWARD will encourage individuals to reach new heights in telescope making.

The Robert E. Cox award will serve two purposes, said Allseits. It will perpetuate the memory of Bob Cox, so that indirectly his enthusiasm and energy will continue to reach people as it did during Bob's life. Also the award will recognize and encourage individuals like Bob Cox who gave tirelessly of their time and energy.

"The award will be presented on a regular basis for outstanding contributions to optics, telescope making, and the promotion of astronomy," said committee member Bopp. The citation on the plaque presented to the Cox family states that "the award honors individuals who have developed uncommon talents, and distinguished themselves by sharing their knowledge and expertise with others."

"But most important," said Berry, "we recognize the extraordinary contribution of time and energy Bob made to helping beginners and youngsters. These people represent the next generation of craftsmen and innovators, and helping them is what we most want to encourage with the Award."

The award will usually be presented at the AstroFest gathering of telescope makers, in keeping with efforts to establish and foster AstroFest traditions. Committee member Troiani, on behalf of AstroFest, noted that Bob was instrumental in developing non-competitive criteria for judging, and also served several times as a judge. "We think of Bob as a founding 'AstroFester,'" said Troiani.

The Cox Award committee is comprised of Thane Bopp, a close friend of Bob and his family for many years, John Allseits, the first chairman of AstroFest (1980-81) and historian of the Chicago Astronomical Society, Dan Troiani, AstroFest awards chairman and assistant Mars recorder for the Association of

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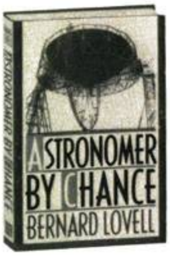
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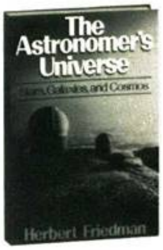
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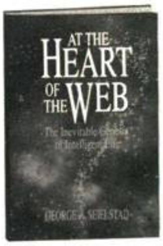
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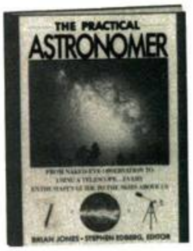
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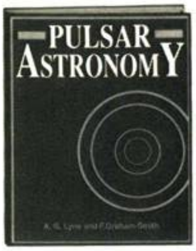
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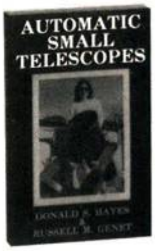
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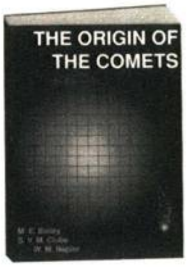
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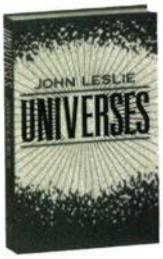
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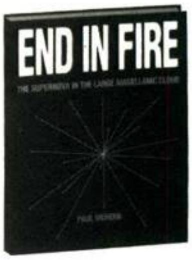

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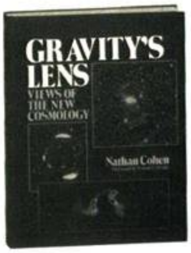
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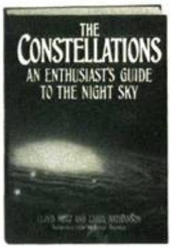
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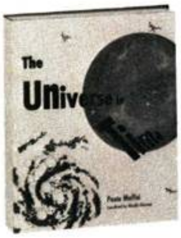
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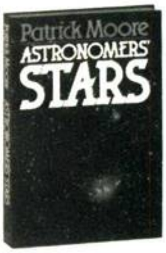
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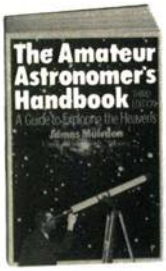
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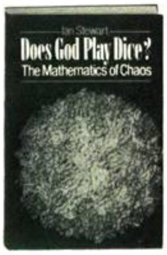
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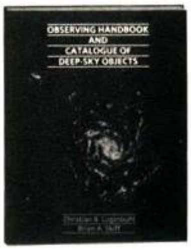
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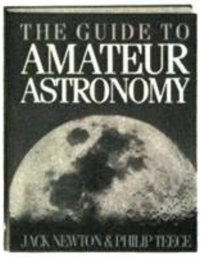
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Lunar and Planetary Observers, and Richard Berry, editor of ASTRONOMY and *Telescope Making* magazines, who worked with Bob for ten years on *Telescope Making*.

More friends of Bob Cox will be invited to join the committee in the coming year, to fully reflect the national scope of the award. Kalmbach Publishing Co., the publisher of both ASTRONOMY and *Telescope Making*, has provided financial support for the Robert E. Cox award, and will sponsor the award in coming years.

The committee will accept names for consideration for the Robert E. Cox Award at any time. The committee will select actual award recipients from a list of nominees. The committee asked that suggestions for candidates for the award be made in writing to John Allseits, 800 E. Allanson Rd., Mundelein, IL 60060 or to any other committee member. ☐

Space News

WHAT'S UP IN SPACE?

1990 is one of the busiest years yet for space science. Here's the status of some of the current missions:

***Magellan* Arrives at Venus** — On August 10, *Magellan* flew over the north pole of Venus, fired its on-board solid rocket motor, and became the first U.S. spacecraft to enter orbit around another planet since 1978's *Pioneer Venus Orbiter*. In fact, *Pioneer* continues to operate, giving us two working spacecraft circling Venus.

Magellan's single experiment, the radar imaging system, was activated August 15 and began sending back remarkable images. Then, the next day mission controllers lost contact with Magellan for about 13 hours. Another loss of contact occurred on August 21.

The signal problems occurred when a computer on board *Magellan* apparently ran amok, pointing the spacecraft away from Earth. Engineers at the Jet Propulsion Laboratory are confident, however, that the spacecraft systems themselves were not at fault. The culprits may have been stray electrical charges from cosmic ray hits or static electricity. Other nail-biting losses of signals are expected throughout *Magellan's* mission. To ease the anxious moments, JPL engineers are designing improved software routines that will place *Magellan* into a safe mode during signal blackouts, which should prevent any catastrophic loss.

At press time, the start of the radar mapping of Venus was being delayed until after engineers better understood *Magellan's* computer problems. Systematic mapping was expected to begin September 19. Over the next year *Magellan's* radar system will peer through the clouds to reveal the surface of Venus in unprecedented detail, showing features as small as 400 feet across. The first test images have already shown volcanoes, earthquake fault lines, and rift valleys.

***Galileo* Returns Home** — *Galileo* is now quietly cruising through the inner solar system. In August, *Galileo* reached its farthest point from the Sun in its present orbit. It then began to fall in toward the Sun and a close flyby across the nightside of Earth on December 8. This will be the first of two gravitational kicks from Earth that *Galileo* will need to boost its speed so it can reach its final target, Jupiter. The next close flyby of Earth will be December 8, 1992, just prior to which *Galileo* will capture a unique time-lapse movie of Earth and the Moon.

On this year's close approach to Earth *Galileo* will play back the images it took at Venus last February. These have been stored onboard until *Galileo* got close enough to Earth to allow the full data to be transmitted through the spacecraft's low-gain antenna. (The high-gain antenna is now folded up to protect it from radiation near the Sun.) Scientists have seen tantalizing glimpses of *Galileo's* Venus images, which show structure in the lower atmosphere that has never been seen before. When *Galileo* returns to Earth in December it will have traveled 650 million miles, with about 2 billion more to go until it reaches Jupiter on December 7, 1995.

The X-Ray Eyes of *ROSAT* — A joint project of NASA, the U.S. Air Force, the United Kingdom, and West Germany, the *Roentgen Satellite*, or *ROSAT*, was launched on a McDonnell Douglas Delta II rocket on May 31. The prime mission is a survey of x-ray sources across the entire sky. The survey began on July 31 and will take six months to complete. (See page 22 for the first images.) For two years after that *ROSAT* will examine in detail some 1,000 of the anticipated 50,000 to 100,000 sources that will be detected.

ROSAT is the first NASA x-ray mission since the *High Energy Astrophysical Observatory-2*, or *Einstein*, in 1979. *Einstein* provided the first true images of x-ray emitting objects. *ROSAT* will also produce x-ray images, but with a far greater resolution and positional accuracy than *Einstein*. The heart of *ROSAT* is a grazing-incidence x-ray telescope that can focus radiation in the 6 to 100 Ångstrom range. A British-built wide field camera will view the sky simultaneously in the 60 to 300 Ångstrom, or extreme ultraviolet, range. Objects that *ROSAT* will explore include the hot atmospheres of distant stars, the remains of supernova explosions, possible black hole candidates, and the matter that exists between galaxies.

A Light Show From *CRRES* — A little heard-of satellite, the *Combined Release and Radiation Effects Satellite* was launched July 25 into a 218- by 20,989-mile elliptical orbit around Earth. The launch was from a General Dynamics commercial Atlas Centaur rocket, the first use by NASA of a privately contracted expendable launch vehicle.

CRRES is a joint NASA/U.S. Air Force mission to study the effects of chemical releases on the Earth's ionosphere and magnetosphere and to monitor the effects of space radiation on spacecraft electronics. In early September, *CRRES* was scheduled to conduct the first release of chemicals over the South Pacific near American Samoa. Subsequent releases are scheduled for sometime in January and February and should be visible from North America as short-lived grey-blue clouds spreading across the night sky.

Ulysses — Slated for launch on the shuttle *Discovery*, *Ulysses* will fly out to Jupiter for the boost needed for its mission over the poles of the Sun. The launch window extends from October 5 to 23. If *Ulysses* misses this window, it's a wait of 13 months for the next opportunity. ☐

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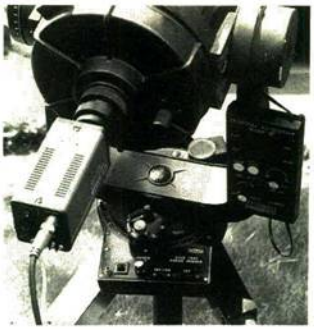
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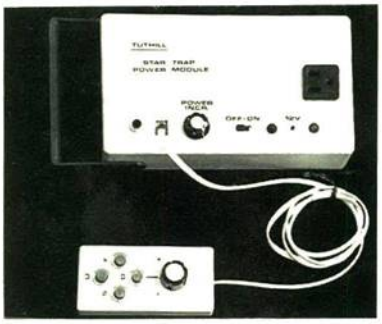

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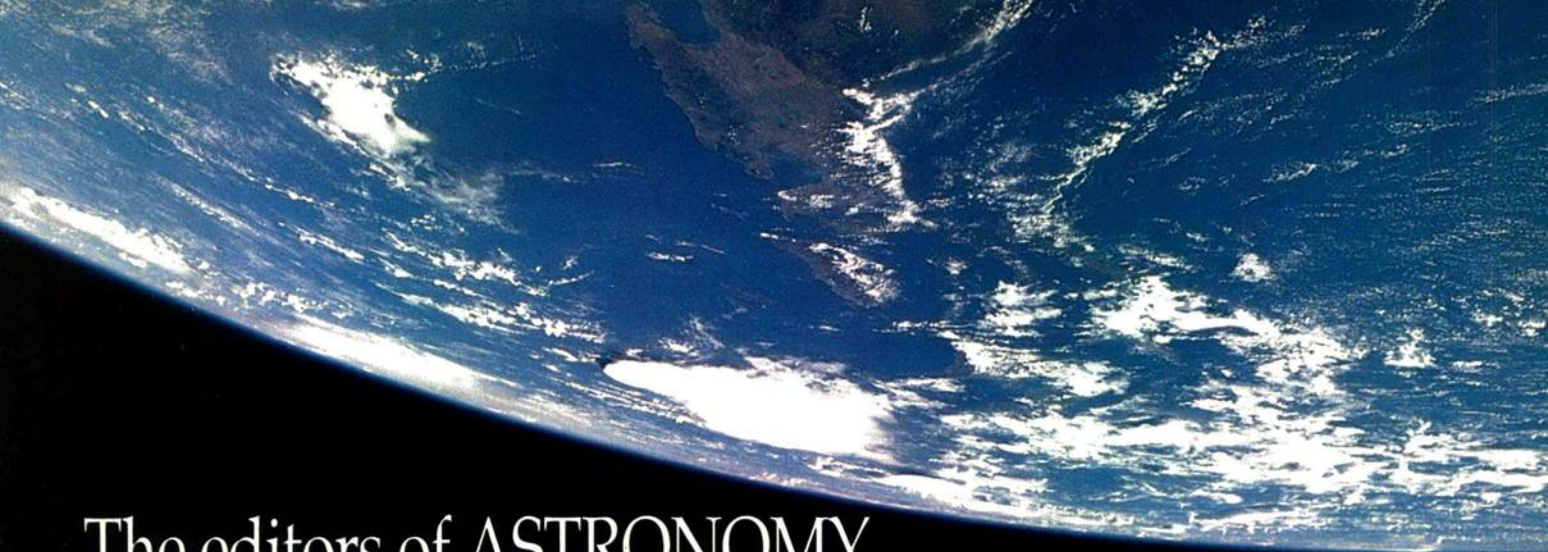

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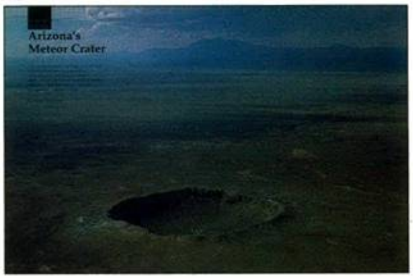
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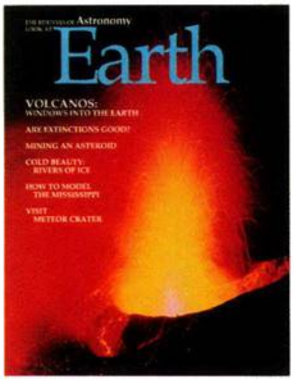
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SPECIAL REPORT

HUBBLE'S OPTICAL FIX

Hubble does not perform as expected, but it can still do a great deal of scientific work. Here's a report direct from the Space Telescope Science Institute about the problems and what astronomers can observe with Hubble until it's fixed.

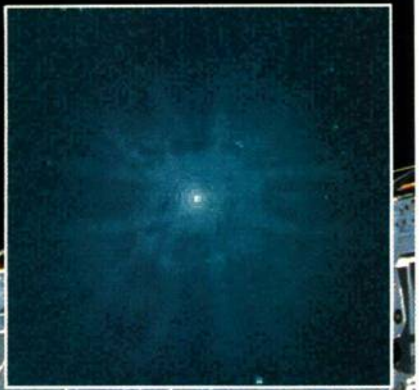
by the Space Telescope Science Institute

The *Hubble Space Telescope* was launched aboard the space shuttle *Discovery* on April 24, and successfully deployed the next day. Unfortunately, a serious and long-term problem with *HST's* imaging performance has been identified. Because of this problem, *HST* will not be able to achieve its full goals for imaging performance in the near future.

Most severely affected are many scientific programs involving visual and high-resolution ultraviolet imaging with the two most crucial instruments: the wide-field and planetary camera (WF/PC) and the faint object camera (FOC).

This report will inform the astronomical community about what is wrong and what the consequences of the optical problem will be. At present, it is important to quantify the performance of the observatory, and NASA and the Space Telescope Science Institute must reexamine their plans for using the observatory.

AT BEST FOCUS spherical aberration dominates *HST's* star images. The image "core" contains about 15% of the light from a star; the remaining 85% is spread into a halo about 1.5 arcseconds across. Photos: NASA and STScI (below).



The Optical Problem

Spherical aberration in the optical telescope assembly causes *HST's* images to fail to meet specifications by a factor of seven: that is, 70 percent of the light falls within an observed radius of 0.7 arcsecond, rather than the specified radius of 0.1 arcsecond.

In simple terms, light from the inner and outer edges of the primary mirror is not brought to the same focal plane; instead, light from the outer edge comes to focus about 4 centimeters behind light from the inner edge.

This aberration has been demonstrated in a series of images taken with the wide-field and planetary camera over a wide range of focus settings of the secondary mirror. Images taken with all eight CCDs (through several different filters) in the WF/PC and with the faint object camera all show the problem.

The size of the image core is close to the diffraction limit expected for *HST* (about 0.1 arcsecond in radius), but contains only about 15 percent of the energy. The core is surrounded by a halo that encircles 70 percent of the energy and extends out to a diameter of about 1.5 arcseconds.

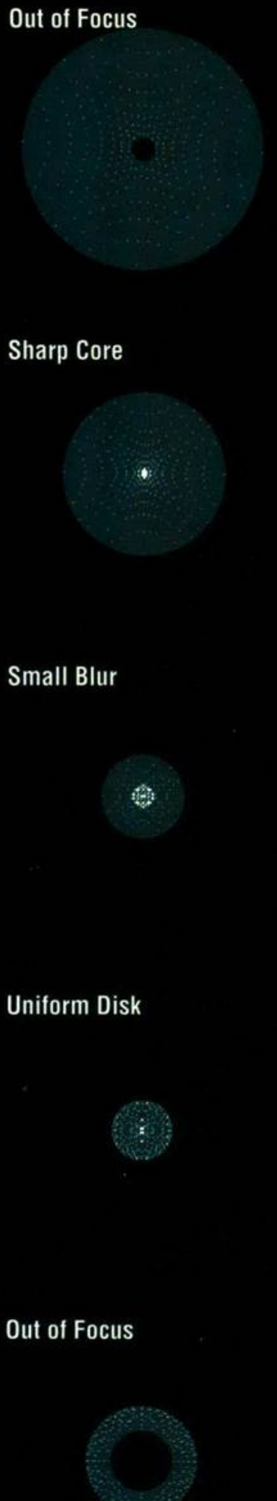
The remaining 30 percent of the light is scattered outside the halo by a combination of mirror microroughness and aperture obscurations into a characteristic "tendril" pattern.

The image is strongly focus- and wavelength-dependent, and it varies with field position in the WF/PC because of the camera's internal vignetting.

Tests show that the faulty optical surface is that of the primary mirror. If it were on the secondary mirror, scans made by the fine guidance system would show evidence of off-axis coma. Although the primary mirror has a set of twenty-four actuators that can apply forces to the mirror's back side, these are not well placed for removal of spherical aberration. Less than 10 percent of the aberration can be removed with the actuators.

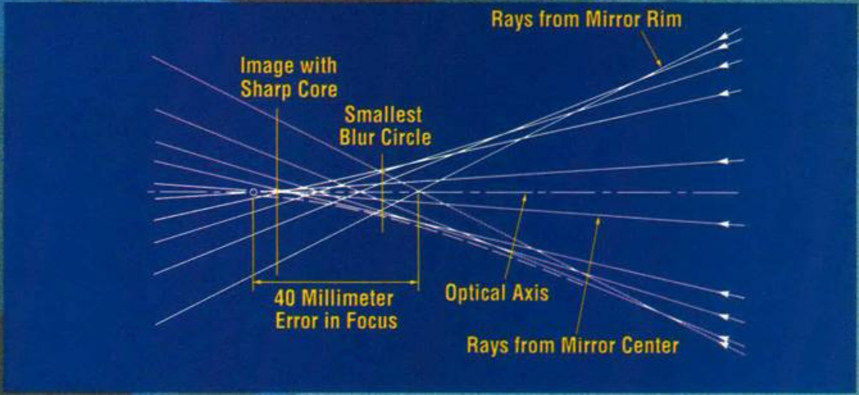
The figure of the secondary mirror cannot be adjusted, but the mirror can be translated and tilted, as well as moved toward or away from the primary. These adjustments are insufficient to remove the aberration.

Spherical Aberration: Fuzzy Star Images


Out of Focus
Sharp Core
Small Blur
Uniform Disk
Out of Focus

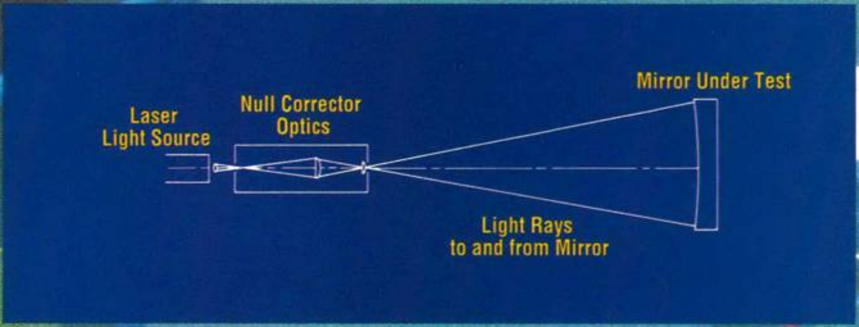
TAKE YOUR PICK of fuzzy images; with spherical aberration there's no truly sharp optical focus.

Spherical Aberration: the Failure to Focus


Rays from Mirror Rim
Image with Sharp Core
Smallest Blur Circle
40 Millimeter Error in Focus
Optical Axis
Rays from Mirror Center

NO SHARP IMAGE FORMS when optics suffer from spherical aberration. Rays from different parts of the mirror do not focus together.

How Did the Error Happen?


Mirror Under Test
Laser Light Source
Null Corrector Optics
Light Rays to and from Mirror

AN ERROR IN MAKING NULL TEST OPTICS caused opticians to polish the outer parts of *HST's* primary mirror too flat.

ALTHOUGH AN IN-ORBIT FIX will eventually restore the *Hubble Space Telescope* to its full image-forming capacity, at present its images are severely degraded. Spherical aberration (left) does not allow a sharp image at any focus. In-orbit testing of the telescope optics (opposite page, top) shows the images are puffed up roughly seven times larger than they should be. Spherical aberration occurs (top) when rays from the telescope's central zones and edge zones do not come to the same focus. The error in the primary mirror almost certainly resulted from an error in the null test lens used for optical testing (above) when the primary mirror was being made.

Impact on the Scientific Instruments

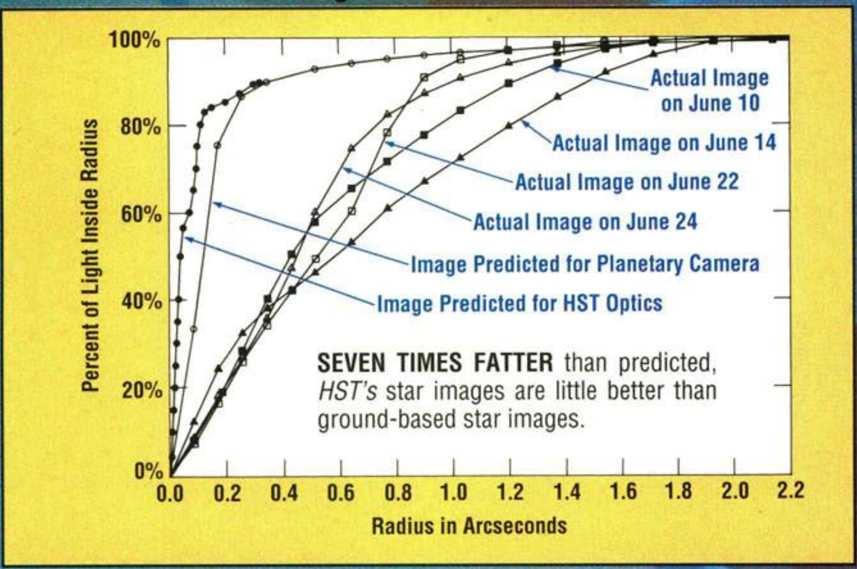
STScI scientists have completed a preliminary critique of the impact of the image quality on the scientific capabilities of the instruments.

Wide-Field and Planetary Camera. The impact is most severe on the WF/PC. Many programs that require the limiting capabilities of the WF/PC will not be able to achieve their scientific goals. However, because 15 percent of the light is concentrated in a sharp image core, *HST* images contain more information than images from typical ground-based telescopes, and *HST* images are expected to be extremely stable. Thus WF/PC programs that involve bright objects may remain viable through use of image-deconvolution techniques; however, these techniques will probably require significant increases in exposure time.

Faint Object Camera. In visible light, the FOC will suffer the same problems as outlined for the WF/PC. Unique scientific programs for imaging in the ultraviolet region that do not require fully diffraction-limited performance remain, but they require longer exposure times than originally planned.

Faint Object Spectrograph. HST's enlarged images will cause

How Bad Is the Image?



SEVEN TIMES FATTER than predicted, *HST's* star images are little better than ground-based star images.

less light to enter the FOS and will reduce spectral resolution, but much FOS science remains viable. Obtaining spectra will still be possible, but the targets will have to be brighter or the exposure times longer. Programs involving isolation of objects in crowded fields will be compromised, and FOS spectroscopy in the visible part of the spectrum can now probably be done as easily from the ground.

High-Resolution Spectrograph. The impact on HRS is similar to that on the FOS. The throughput of the 0.25-arcsecond aperture is reduced by a factor of five below that originally expected. The 2.0-arcsecond aperture will have about half the expected throughput, and there will be some loss of spectral resolution.

High-Speed Photometer. Although the HSP will suffer from reduced throughput and from noise due to guiding jitter (especially through its small aperture) many programs with the HSP will not be impacted at all.

Fine Guidance System. Most astrometric programs remain viable, so the astrometry capability is apparently not compromised at all.

Scientific Capability

The *Hubble Space Telescope* is an extremely versatile observatory. Despite the loss of image quality, many of its modes of observing remain largely or even wholly intact. Many observations are possible because *HST*, even in its present state, has unique capabilities that cannot be matched either in space or on the ground. With the remaining capabilities of *HST*, astronomers will be able to do forefront science 100 percent of the time, even though the initial scientific emphasis must now be different. Thus viable scientific programs will easily occupy all the time available on *HST* and will return scientific results of great interest and utility.

Planned Course of Action

After final alignment of the optics, the wave-front errors of the optical telescope assembly will be mapped in detail. The second-generation scientific instruments now being developed could thus incorporate compensating optics which, it is currently anticipated, could completely remove the spherical aberration.

A shuttle mission to revisit *HST* had already been planned for 1993. It is possible, for example, that the WF/PC II currently under development at the Jet Propulsion Laboratory could be fitted with corrective optics and installed by that time.

It is likewise anticipated that the space telescope imaging spectrograph (STIS) and near-infrared camera and multi-object spectrograph (NICMOS) planned for installation in 1995 or 1996 will be able to achieve nominal spectroscopic, imaging, and infrared performance through the addition of compensating optics.

Conclusions And Recommendations

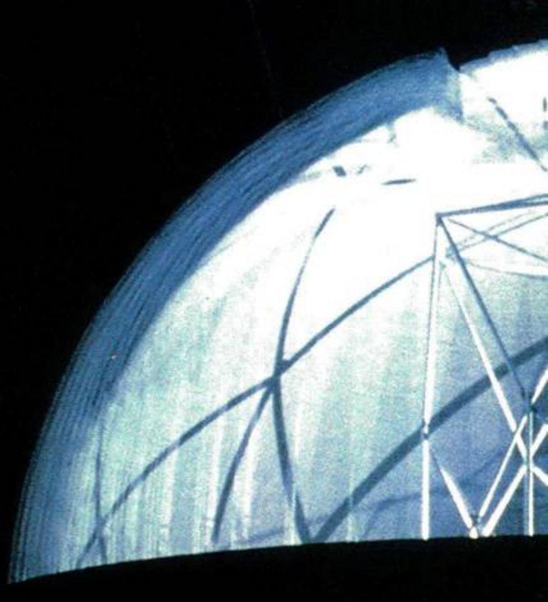
Although the program has clearly suffered a major setback, STScI is convinced that the prospects for completion of the science program are highly encouraging. *HST* right now has capabilities that vastly exceed ground-based observatories. A valuable subset of *HST's* scientific program can be executed with the telescope even in its present state. The result is that *HST* still has the potential to produce key discoveries in several areas in the near future, long before the optical flaws are fully corrected.

Nearly everyone agrees that all necessary actions should be taken to insure that *HST* operates as productively as possible in the short-term and that activities that will restore full capability over the long-term should be pursued vigorously. This means supporting ongoing *HST* operations fully and encouraging STScI to continue evaluating and analyzing the telescope and instrument performance.

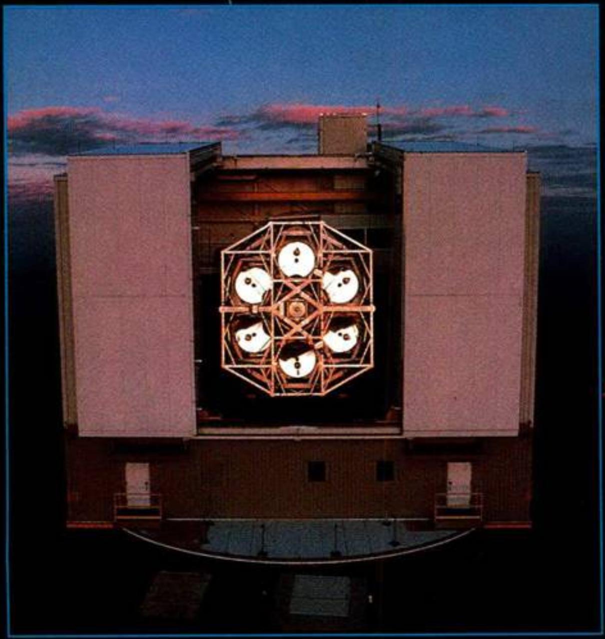
By way of conclusion, it should be emphasized that an enormous number of technically difficult challenges involved in the design of *HST* have been successfully met. These include the basic smoothness of the optics, the high degree of accuracy required from the pointing control system, and the proper functioning of a suite of complex scientific instruments, to name only a few.

Compared to the huge investment already made in *HST*, the effort involved in correcting the optical aberrations is small. Likewise, the delay until delivery of WF/PC II is short compared to planned 15-year duration of the project. Keeping this perspective in mind, it is important to keep our eyes on the future and work diligently to realize the full potential of the observatory, which is still a fully viable goal. □

ASTRONOMY wishes to thank Albert Boggess, NASA project scientist for HST, *the members of the* HST *Science Working Group, Arthur Davidson and the* HST *Users Committee, Howard E. Bond, User Support Branch, and Chris Burrows, Telescope and Instruments Branch of STScI.*



THE LARGEST OF THE NEW SCOPES and the earliest to receive first light is the 10-meter Keck telescope on Mauna Kea. Here the huge telescope sits inside its rotating dome. © 1990 by Roger Ressmeyer — Starlight from the SPACE PLACES Project.



THE SIX MIRRORS OF THE MMT will soon be replaced by a single mirror 6.5 meters in diameter, as astronomers strive for more light-gathering power. Nevertheless, many of the telescopes planned for the 1990s will make use of the multiple-mirror concept. MMT Observatory photo.

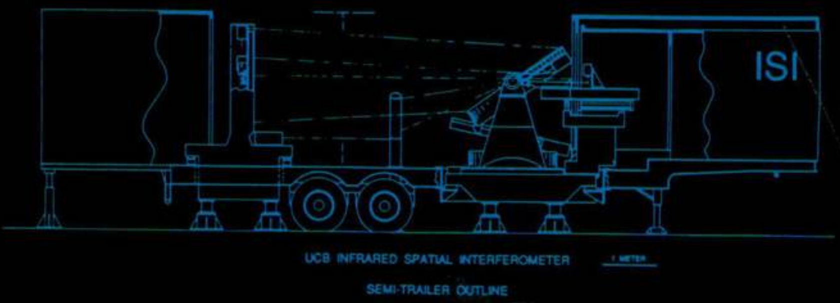
Optical Astronomy Looks to the Future

The decade of the 1990s promises a renaissance in ground-based astronomy.

by Barney Magrath

Ever since Galileo turned his primitive spyglass to the heavens, astronomers have sought bigger and better telescopes. But the rush toward ever larger telescope mirrors slowed considerably by the middle of the twentieth century. In fact, the largest fully productive telescope in the world today is still the 200-inch Hale telescope on Palomar Mountain, and that was dedicated more than forty years ago.

Astronomers have never lost their desire for bigger telescopes, however. Their quest for larger telescopes is fueled by two overriding desires. First is a desire for more light, because the more light a telescope gathers, the fainter the objects it can see. Only giant telescopes can record the feeble light emitted by galaxies



THE HIGHEST RESOLUTION IMAGES of the 1990s will come from interferometers in which two or more telescopes observe in unison. In the Infrared Spatial Interferometer, the telescopes are based in semi-trailers so the distances separating them can be changed. University of California, Berkeley, diagram.

near the edge of the universe and analyze it in detail. And there are dozens of other research areas where sheer light-gathering power is essential.

The second reason astronomers desire larger telescopes is so they can get a sharper look at the heavens. The amount of detail a telescope can reveal in a celestial object is proportional to the diameter of the telescope's mirror. Astronomers wanting to study close binary and multiple star systems, stellar surfaces, or the nuclei of active galaxies and quasars, for instance, would benefit from larger telescopes with better resolution.

Until recently, however, astronomers considered mirrors larger than 5 meters (200 inches) in diameter a dubious and prohibitively expensive undertaking. To keep such a mirror rigid enough so it would not lose its figure during an observation, the mirror had to be thick, and a large, thick mirror has an enormous weight. The largest monolithic mirror on the planet, the 6-meter (234-inch) behemoth at the Soviet Union's Special Astrophysical Observatory in the Caucasus Mountains, weighs in at 84,000 pounds! The tremendous weight of the mirror is a major reason why the telescope has never lived up to expectations — by the time the big mirror reaches thermal equilibrium, the night is over.

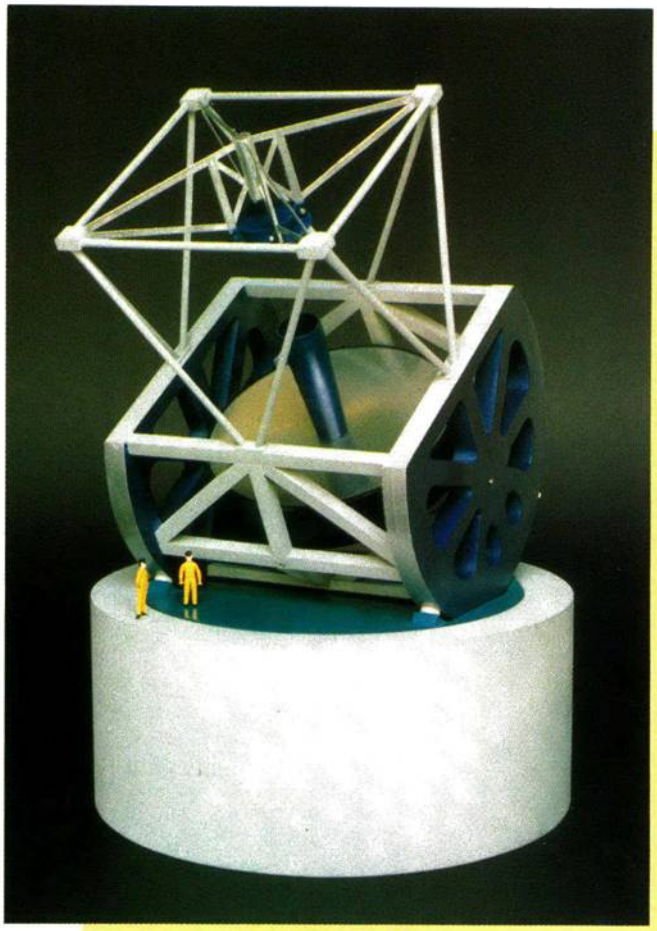
Yet most professional astronomers now are convinced that a new breed of technologically advanced, ground-based telescopes and observatories need to be built in the 1990s if we are to continue to push back the frontiers of observational astronomy. And it appears that their desires will be realized. There are plans to build more than a dozen of these new-breed telescopes during the coming decade, and a few of them are far enough along that they should be finished within a year or two.

To satisfy the desire for more light-gathering power, astronomers are turning to large, single-mirror designs — telescopes 8 meters (315 inches) in diameter and larger. No, they haven't repealed the laws of physics governing large telescope optics. Instead, engineering advances now allow us to make large, lightweight mirrors that are either rigid enough to keep their shape or thin enough that they can be deformed into the proper shape.

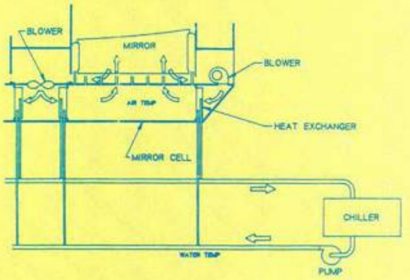
To gain significant increases in resolving power, astronomers are turning to a completely new kind of "telescope," the optical interferometer array. Such an array is a computer-linked system of two or more telescopes that together yield a resolution equivalent to a single telescope as large as the distance between the individual telescopes. The technique has been used successfully in radio astronomy for many years to achieve high-resolution images. Now the technology exists to expand that success into optical astronomy.

Make Me a Mirror

Building a bigger mirror seems easy at first glance. Any engineer could tell you the solution to the problem — make the mirror lighter. But making a large, lightweight mirror that will hold its shape no matter where in the sky it is pointing is far from easy. The complexity of the task is just part of the reason that three fundamentally different approaches are being used to produce the huge mirrors.



ONE OF THE FIVE 8-METER MIRRORS to be cast by Roger Angel and his staff is destined for Chile and the Magellan Project. The mirrors keep their shape thanks to a unique honeycomb design. Magellan Project model.

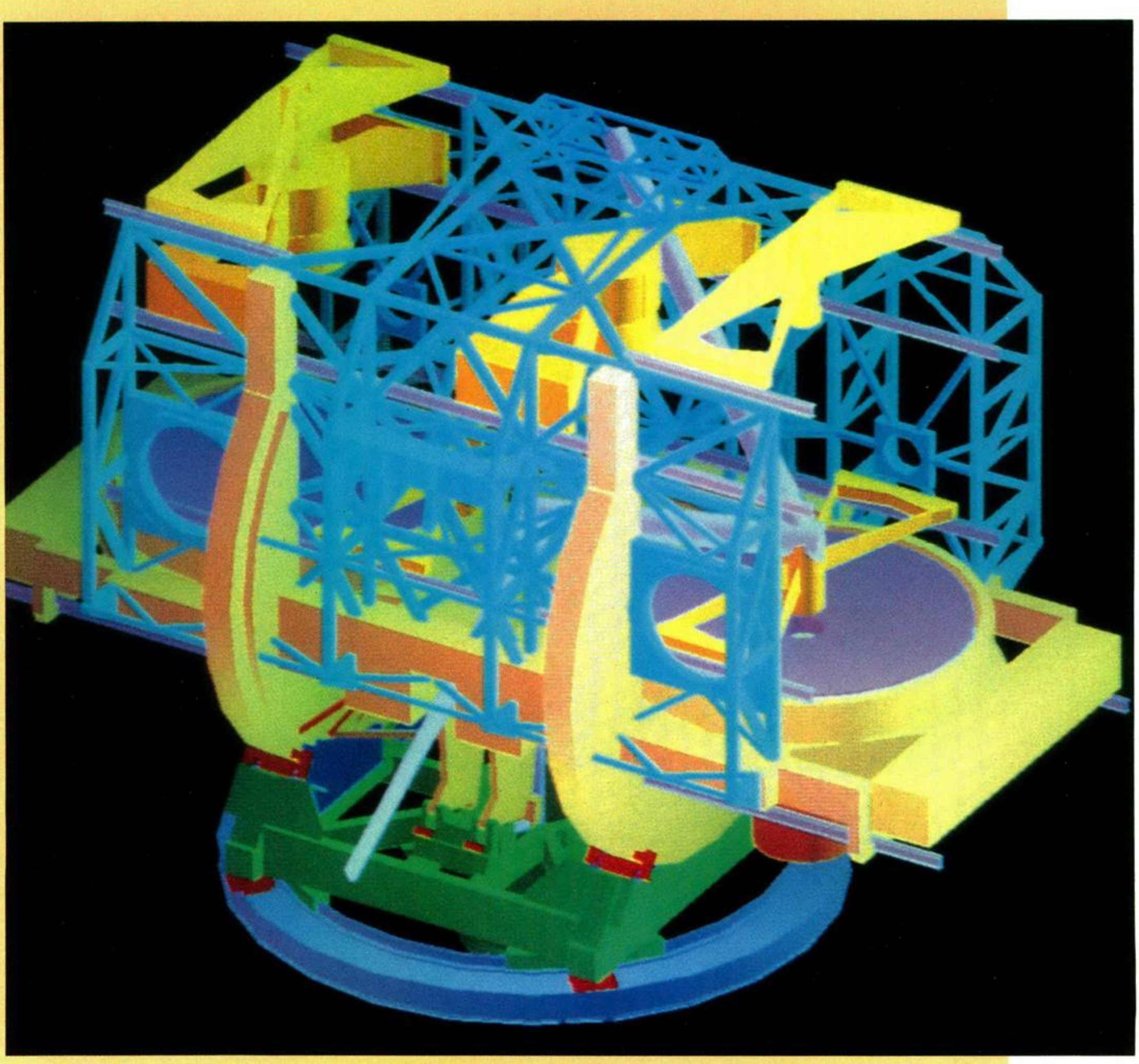


TO GET THE SHARPEST VIEWS, astronomers must keep a telescope's mirror at air temperature. In the WIN telescope, conditioned air will circulate into the cavities of the honeycomb mirror. NOAO/AURA illustration.

These approaches are the structurally rigid, honeycomb mirror; the thin, flexible, meniscus mirror; and the segmented mirror. One feature all three types of mirror have in common is a small focal ratio. The focal ratio of a mirror is found by dividing the mirror's focal length — the distance from the mirror to the plane where the image is formed — by the diameter of the mirror. For example, an 8-meter mirror that focuses an image 9.6 meters away has a focal ratio of f/1.2. All of the large mirrors planned for the 1990s have focal ratios in this ballpark.

One huge advantage that small focal ratio mirrors

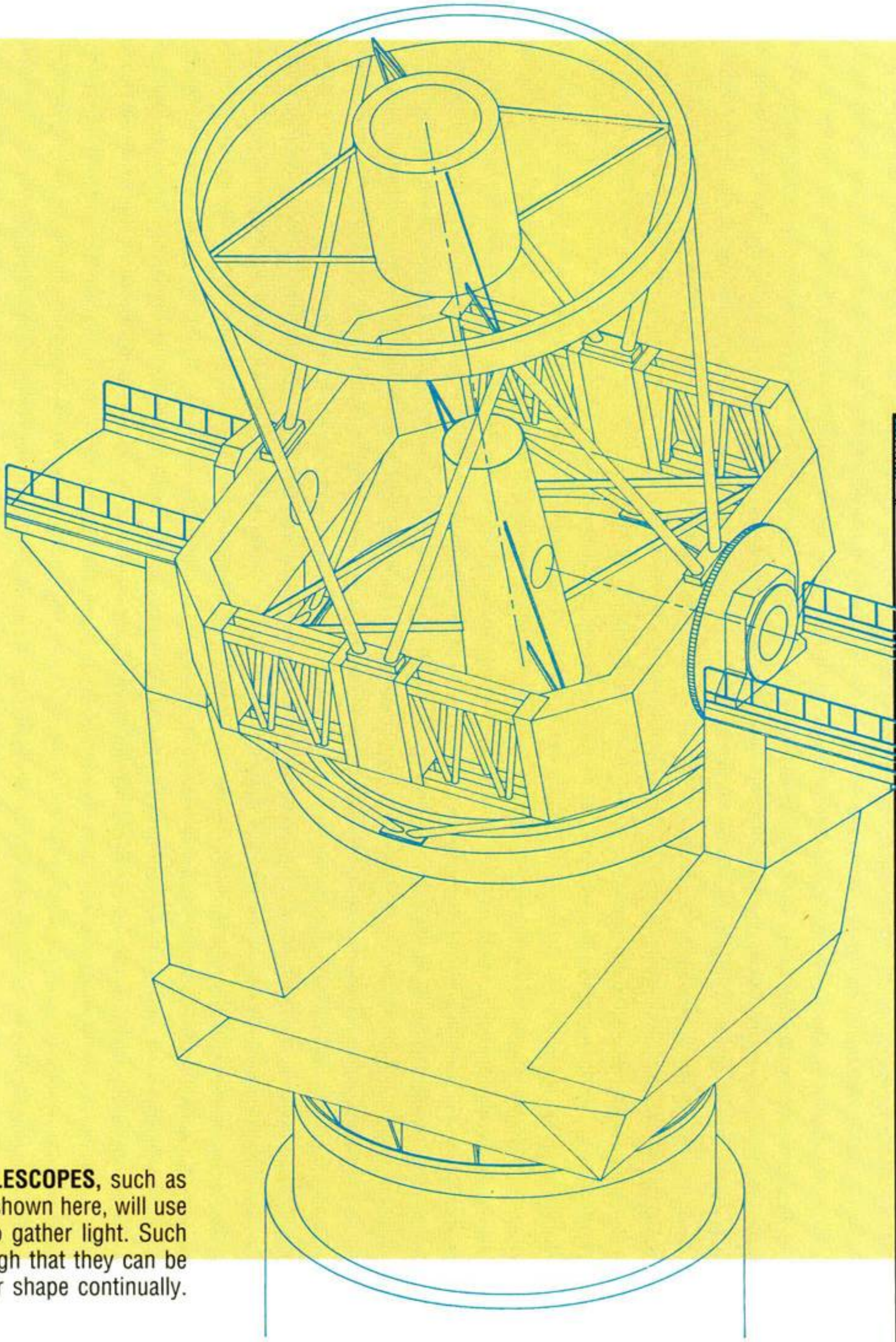
THE WORLD'S LARGEST BINOCULARS will belong to astronomers on the Columbus Project. The telescope's two 8-meter mirrors will gather as much light as a single mirror 11.3 meters in diameter. Columbus Project Office image.



have over large ones is that the support structure can be made relatively short and manageable. Engineers like to say they are "trading silicon for steel." And managers like the idea of smaller and hence less expensive structures.

A majority of the new giant telescopes will use large, honeycomb mirrors made out of borosilicate glass. These mirrors are the brainchild of Roger Angel and the staff of the Steward Observatory Mirror Laboratory located in Tucson, Arizona. They were looking to produce a mirror that possesses five important qualities. First, the mirror has a low mass, which means the mounting can be lightweight. Second, the mirror is structurally rigid, so it can keep its shape without computer control. Third, the mirror is well-behaved thermally and so will reach ambient air temperature quickly and uniformly. Fourth, the mirror makes efficient use of materials, which reduces the cost by reducing the amount of raw materials needed. And fifth, the mirror can be produced and finished in a relatively short time, which again reduces the cost.

Angel and his staff spent years designing and building a manufacturing process to bring these ideas to fruition. At the heart of the process is a remarkable



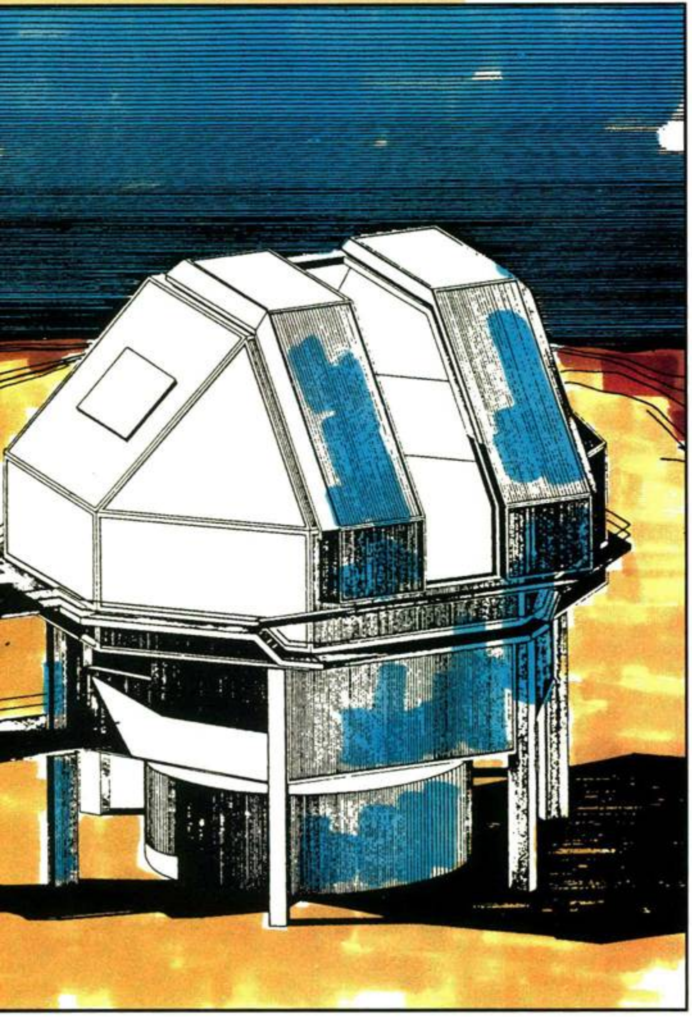
MANY OF THE NEW TELESCOPES, such as the UK Large Telescope shown here, will use thin meniscus mirrors to gather light. Such mirrors are flexible enough that they can be deformed into the proper shape continually. SERC diagram.

rotating furnace that can cast one-piece, lightweight, structurally rigid mirror blanks. Here's how it works. A complex, honeycombed mold is assembled out of specially machined ceramic pieces atop a large turntable. The mold is then filled carefully with grapefruit-sized pieces of borosilicate glass. Then a 40-ton, overhead crane lowers a specially fabricated lid over the mold and onto the turntable. The inside of the lid is lined with electric heaters, which will melt the glass. In the most crucial step, laboratory engineers start the turntable smoothly rotating and apply 2 megawatts of power to the heaters. The chunks of solid glass slowly turn into a small sea of liquid glass as the furnace reaches a maximum temperature of 1180° Celsius. The glass flows into the shape of the mold and centrifugal force from the turntable's rotation causes the top surface of the liquid glass to assume a concave, parabolic shape. After approximately 24 hours, the turntable is stopped, and then the mirror blank is very slowly cooled over the course of about a month to prevent stresses from distorting the mirror. Fine polishing finishes the process.

To date, three 3.5-meter (138-inch) mirrors have been manufactured successfully using this method. One will be installed in the **ARC telescope** at Apache Point Observatory in Sunspot, New Mexico. First light for this telescope is scheduled for 1991. The second mirror is owned by the **Weapons Laboratory** of Kirtland Air Force Base, and will call Albuquerque, New

THIN AND FLEXIBLE MIRRORS

IMPROVING AIR FLOW through a telescope's dome can improve the seeing markedly. One concept being considered for the European Southern Observatory's Very Large Telescope is a pyramidal structure with a large slit. ESO diagram



Mexico, home. It should also receive first light in the coming year. The third will be the primary mirror for the **WIN telescope**, which will join the many telescopes on Kitt Peak in Arizona. First light for the WIN telescope won't come until 1993.

The Steward Observatory Mirror Laboratory furnace is now scheduled to spin a 6.5-meter (256-inch) mirror blank for the Multiple Mirror Telescope (MMT) on Mt. Hopkins, Arizona. The new **MMT** will no longer have multiple mirrors — the six 1.8-meter (72-inch) mirrors in the current scope will be replaced by the single 6.5-meter mirror. Even though the present MMT has performed exceptionally well in all respects, University of Arizona and Smithsonian Institution astronomers realize that to stay at the forefront of astronomical research, they need a telescope that can gather as much light as possible. And a 6.5-meter mirror will collect over twice as much light as six 1.8-meter mirrors.

After the new MMT mirror is cast in February 1991, a mold 8 meters (315 inches) in diameter will be built atop the same turntable. This is the biggest mirror Angel's equipment will be able to make. Plans currently exist for five of these 8-meter mirrors. The **National Optical Astronomy Observatories** will build two 8-meter telescopes, one on Mauna Kea in Hawaii and one at Cerro Pachon, Chile, with first light scheduled for 1997. The **Magellan project**, a collaboration among the Carnegie Institution of Washington, Johns Hopkins University, and the University of Arizona, also plans to build an 8-meter telescope in the mountains of Chile. This one will be located at Carnegie's observatory site in Las Campanas and is expected to receive first light in 1996.

All three of these 8-meter telescopes will use the same telescope and dome design in an effort to share the large development costs. (Each scope is expected to cost about $45 million.) These telescopes will not be housed in traditional domes. Instead, a new kind of structure that allows for smoother air flow, and thus better seeing, is being designed.

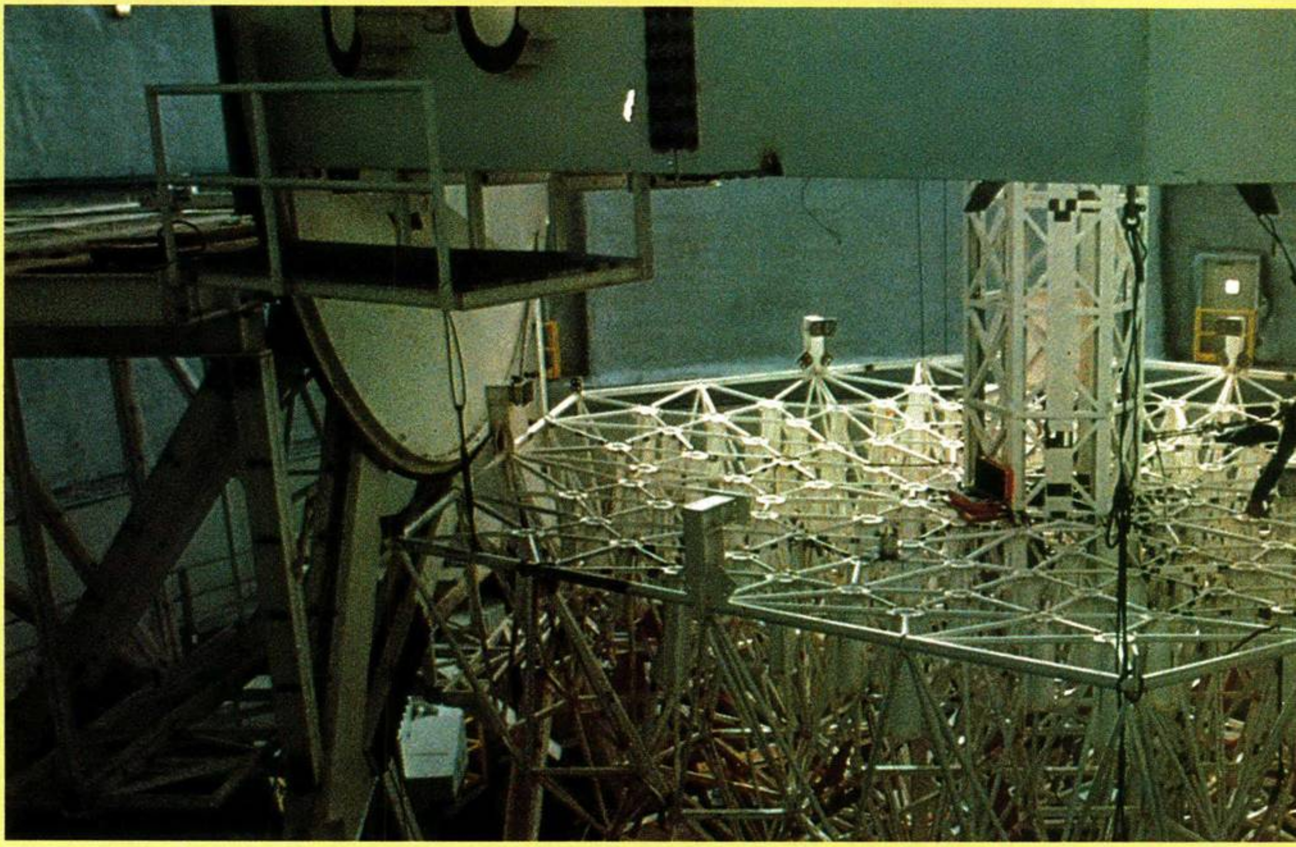
The other two 8-meter mirrors on order belong to the **Columbus project**. An international collaboration involving the Ohio State University, the University of Arizona, and Arcetri Astrophysical Observatory in Italy plans to place the two mirrors side by side to form the world's biggest binocular. (It will also be the world's heaviest binocular, weighing in at 700,000 pounds.) This instrument will have the light gathering power of a single 11.3-meter (448-inch) mirror and the resolving power of a 22-meter (866-inch) telescope. If current plans hold true, project astronomers are hoping for first light on Mount Graham in Arizona in 1994.

Thin and Flexible

Not all project managers consider the honeycomb mirror to be the best solution to the big mirror problem, however. The European Southern Observatory (ESO) has sponsored a technology development program with the goal of producing a thin meniscus mirror for their 8-meter telescope projects. A large, thin meniscus mirror is shaped like a giant contact lens.

The key to making this mirror work lies in its thinness. The diameter to thickness ratio of this type of mirror is forty-six to one, making the mirror over four times thinner in relation to its diameter than the normal value of ten to one. Such an ultra-thin mirror is flexible enough to be "pushed" into the proper optical shape. ESO has followed this approach because they want the telescope to be able to collimate itself. Their opticians found that image quality at the telescope suffers because the optics are often out of alignment. The proper alignment procedures are so unfriendly and cumbersome that technicians and astronomers avoid them. With a thin mirror and the proper equipment to analyze the images it forms, astronomers can automatically recompute and then alter the front surface of the mirror as often as needed.

To prove this concept works, ESO built the 3.5-meter (138-inch) New Technology Telescope as a prototype active optics instrument. (See "An (Optical)



THE NEW GENERATION OF TELESCOPES

LARGE TELESCOPES

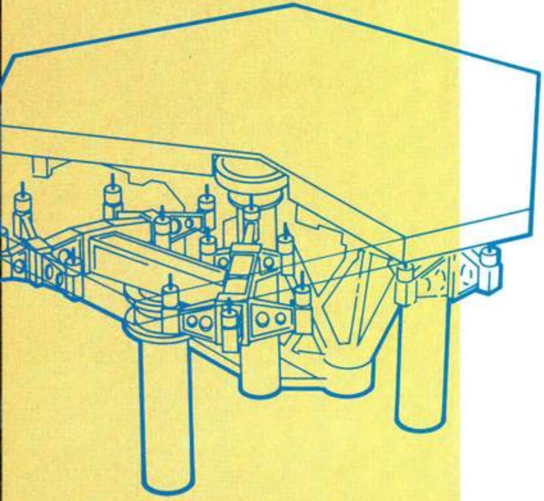
Name	Location	Mirror Size	First Light
New Technology Telescope	La Silla, Chile	3.58 meters	1989
Keck Telescope	Mauna Kea, HI	10 meters	1990
ARC Telescope	Sunspot, NM	3.5 meters	1991
Weapons Lab	Albuquerque, NM	3.5 meters	1991
MMT	Mt. Hopkins, AZ	6.5 meters	1993
WIN Telescope	Kitt Peak, AZ	3.5 meters	1993
Columbus Project	Mt. Graham, AZ	two 8 meters	1994
Very Large Telescope	Chile	four 8 meters	1995
Magellan Project	Las Campanas, Chile	8 meters	1996
National Optical Astronomy Observatories	Mauna Kea, HI	8 meters	1997
National Optical Astronomy Observatories	Cerro Pachon, Chile	8 meters	1997
Japanese National Large Telescope	Mauna Kea, HI	7.5 meters	?
United Kingdom Large Telescope	To be announced	8 meters	?

INTERFEROMETERS

Name	Location	Telescopes	First Light
Mark III	Mt. Wilson, CA	2	working
Infrared Michelson Array	Laramie, WY	2	working
Infrared Spatial Interferometer	Mt. Wilson, CA	2	working
Infrared-Optical Telescope Array	Mt. Hopkins, AZ	2	1992
Big Optical Array	Arizona	6	1992
USNO Astrometric Interferometer	To be announced	4	1993
Center for High Resolution Astronomy	Flagstaff, AZ	7	1995

THE KECK'S SEGMENTED MIRROR

THIRTY-SIX HEXAGONAL MIRRORS will act as one when supported by the massive, welded-steel mirror cell of the Keck Telescope (left). CARA image.



THE PRECISE POSITIONING of each mirror segment is accomplished by a system of three actuators that hold each segment at 36 support points (above). CARA diagram.

Revolution in Chile" on page 44.) The immediate success of the NTT upon completion in 1989 supports the belief that the same mirror support technology can be installed behind an 8-meter mirror. ESO now plans to construct four 8-meter telescopes as part of its **Very Large Telescope** facility (VLT). The four identical, independently mounted telescopes will be installed on one mountaintop and can be used either separately or as an interferometric array. The first of the four scopes is scheduled for completion in 1995, with the complete array being finished by 1998.

The proposed **Japanese National Large Telescope** (JNLT) will also employ a meniscus mirror. Their idea is to support the back of the 7.5-meter (295-inch) primary mirror with 390 actuators and recompute the shape of the mirror 10 times a second. The Japanese, along with astronomers from nine other countries who already people the summit, consider Mauna Kea the most favorable site.

The British have also proposed an 8-meter optical/infrared telescope, called the **United Kingdom Large Telescope** (UKLT). This scope will be modeled on the highly successful 4.2-meter (165-inch) William Herschel telescope on La Palma in the Canary Islands. As with the Japanese telescope, it may also be located on Mauna Kea. Neither of these projects has yet to finalize its plans.

E Pluribus Unum

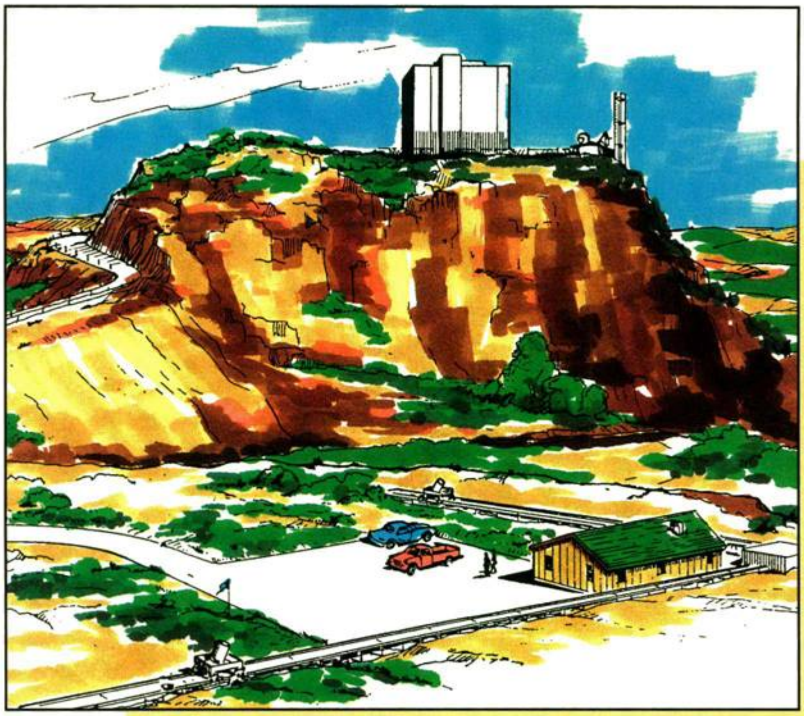
The final word on large telescope mirrors is the unique approach taken with the 10-meter (394-inch) segmented mirror of the **Keck telescope**. A joint project of the California Institute of Technology and the University of California, the Keck is now nearing completion on the summit of Mauna Kea. This telescope will be the largest single telescope in the world through at least the year 2000.

The design scheme behind the Keck mirror is the notion that a large mirror can be assembled from pieces, much like a jigsaw puzzle. The pieces themselves are thin, so the mirror as a whole is lightweight. However, what this mirror possesses in lightness is made up for in its amazingly complicated mirror cell. Each of the 36 mirrors that make up the 10-meter primary is supported by three computer controlled actuators that control the figure of the mirror.

First light for the Keck was scheduled to take place in late September with nine of the mirror segments in place. Phasing those elements together and bringing the other 27 segments on line should be finished sometime in 1991. This is currently the only project using the segmented mirror concept because it is costly — the price tag is about $70 million — and there remains some technological risk because no prototype was built.

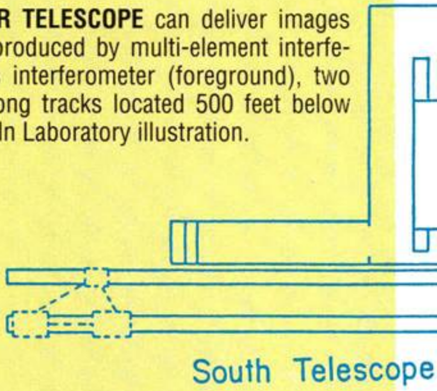
More Mirrors Mean Sharper Images

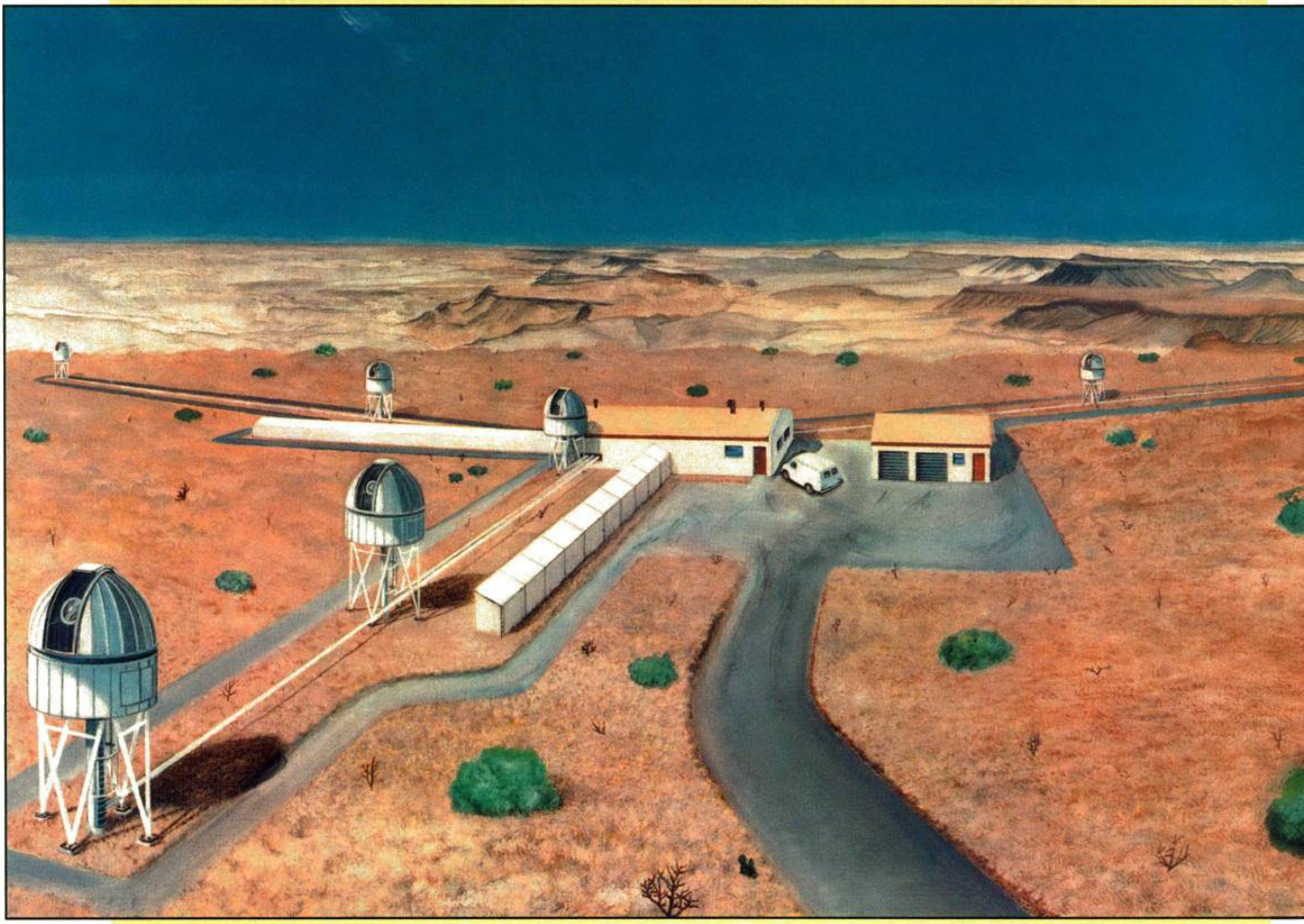
The large telescope projects detailed above represent a specific approach of the decision makers to the advancement of ground-based astronomy in the 1990s. However, as the mirror makers have demonstrated, there is often more than one solution to a problem. And the biggest problem remaining for astronomers is that the increase in resolution provided



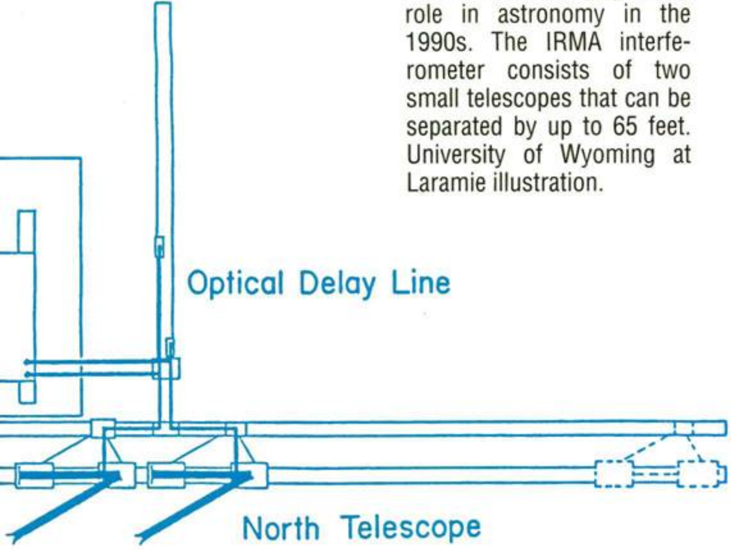
HIGH-RESOLUTION INTERFEROMETERS

NO SINGLE-MIRROR TELESCOPE can deliver images as sharp as those produced by multi-element interferometers. In IOTA's interferometer (foreground), two telescopes move along tracks located 500 feet below the MMT. MIT Lincoln Laboratory illustration.





SEVEN TELESCOPES WORK TOGETHER in the CHARA interferometer. The Y-shaped configuration will stretch across 400 meters of the Anderson Mesa near Flagstaff, Arizona. CHARA illustration.



INFRARED INTERFEROMETERS will also play a big role in astronomy in the 1990s. The IRMA interferometer consists of two small telescopes that can be separated by up to 65 feet. University of Wyoming at Laramie illustration.

by a single 8-meter mirror is not enough to compete with a new breed of space-based instruments.

The solution is the development of a revolutionary type of optical telescope in the 1990s: the optical/infrared interferometer. Advances in telescope design, detectors, and computer control systems now make interferometers that work in the optical and infrared windows practical. Whereas large, single-mirror telescopes can achieve resolutions in the vicinity of 0.5 arcsecond, interferometers are designed to achieve incredible resolutions on the order of 0.05 arcsecond.

One approach to the design of an interferometer is that of the European Southern Observatory's planned Very Large Telescope. The four telescopes in this instrument will be able to simultaneously observe a single object and thus resolve smaller details than any one of the telescopes could by observing alone. However, most of the interferometers planned for the 1990s will use much smaller telescopes — on the order of one meter in diameter — that can be placed much farther apart.

So far, the only working optical/infrared interferometers are experimental instruments that cannot form images. Why not? The current generation of optical/infrared interferometers possess only two telescopes, or array elements, on a single straight baseline. The most famous imaging array, the Very Large Array (VLA) radio telescope, has 27 array elements arranged in a Y-shaped pattern. In order for the optical/infrared interferometers to image like the VLA, they will have to be set up in a similar arrangement.

Because the field of optical/infrared interferometry is in the "proof of concept" stage, the research money for large numbers of array elements has just not been available. The most successful operating long-baseline optical interferometer in the United States is the **Mark III** interferometer on Mt. Wilson, California. This is a two-telescope array that scientists from the Naval Research Laboratory, the U. S. Naval Observatory, MIT, and the Smithsonian Astrophysical Observatory have used to measure directly the diameters of 50 stars.

The success of the Mark III has led to the design of the **Big Optical Array** (BOA). The BOA will consist of six telescopes mounted on a Y-shaped baseline that encompasses at least 250 meters (800 feet). The project is fully funded and prototypes are being fabricated, though construction has not yet begun at the preferred site in Arizona. Naval Research Lab astronomers expect first light in 1992 and to have the interferometer in full operation by 1993.

A second instrument being built as part of the same project as the BOA is the **United States Naval Observatory's Astrometric Interferometer**. This USNO instrument will consist of four telescopes situated some 20 to 40 meters from each other and is scheduled for completion in 1993. The major scientific goal of the astrometric interferometer is to set up and maintain an extremely accurate celestial coordinate frame by precisely measuring the positions of stars, galaxies, and quasars.

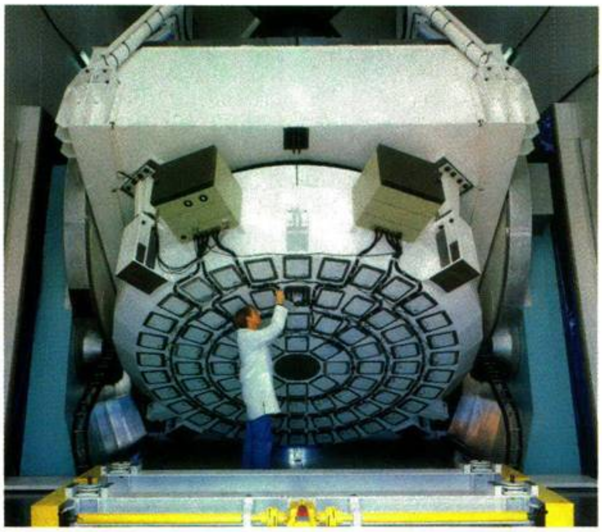
Astronomers involved with the **Center for High Angular Resolution Astronomy** (CHARA), a collaboration between Georgia State University and Georgia Tech, are also promoting an optical imaging array. Their plan envisions seven collectors arranged in a Y-shaped configuration having a diameter of 400 meters (1,320 feet). CHARA astronomers have chosen Anderson Mesa near Flagstaff, Arizona, as the most favorable location for their interferometer and hope to have the array operational by 1995.

Optical imaging arrays will be a breakthrough in astronomical imaging technology, but they are not the only useful interferometers. The astronomers who design these kinds of telescopes believe just as much science can be done with a two-element array as with a seven-element array.

Astronomers at the University of Wyoming are testing a near-infrared interferometer called the **Infrared Michelson Array** (IRMA). This instrument has two collectors on a 20-meter long baseline that runs north-south. Scientists from the University of California, Berkeley, also are testing a two-element interferometer. Called the **Infrared Spatial Interferometer** (ISI), it will observe at wavelengths in the middle of the infrared window. Each telescope will be mounted in a semi-trailer, and the semi-trailers will move along a 34-meter baseline. Finally, the **Infrared-Optical Telescope Array** (IOTA) is a two-element array planned for completion in 1992. It will be located near the summit of Mt. Hopkins, Arizona, about 500 feet below the MMT.

It's quite possible that some of the big mirror projects and interferometers planned for the 1990s won't be built, simply because there's not enough money to do everything astronomers would like to do. But there's no question that the groundwork has been laid for a major renaissance in telescope construction. The flood of astronomical discoveries that will surely flow from these new instruments promises to make the 1990s a golden decade for astronomy. And with any luck, the positive momentum will last well into the new century. ☐

Barney Magrath is an instrument technician for the 3.6-meter Canada-France-Hawaii telescope at the summit of Mauna Kea, Hawaii. He is also an avid astrophotographer whose work has appeared in ASTRONOMY.



AN (OPTICAL) REVOLUTION IN CHILE

At the European Southern Observatory's New Technology Telescope, the future is ***now***.

by Joel K. Harris

It is the end of another hot, dusty day in the southern end of the Atacama Desert in central Chile. Many of the local townspeople traveling along the winding route of the Panamerican Highway are heading home from the farms and mines that dot the barren landscape. Save for the bright sunlight and the dense atmosphere, this terrain seems more akin to that of Mars than that of Earth. In this unforgiving land, atop a 2,400-meter mountain saddle, sits one of the great modern optical observatories in the world, the European Southern Observatory's La Silla facility.

It takes about an hour to drive up the sinuous road from the main highway turnoff to the summit of La Silla (Spanish for "the saddle"). Unlike my previous visits to the European Southern Observatory (ESO), however, this one was attended by the unsettling question: "With the advent of orbiting observatories like the *Hubble Space Telescope*, what will become of ground-based observatory sites like La Silla?" Although the subsequent problems with *HST* may have postponed the day of reckoning, I couldn't help but wonder whether the inevitable deployment of space-based observatories would one day bring about the demise of big-time ground-based astronomy.

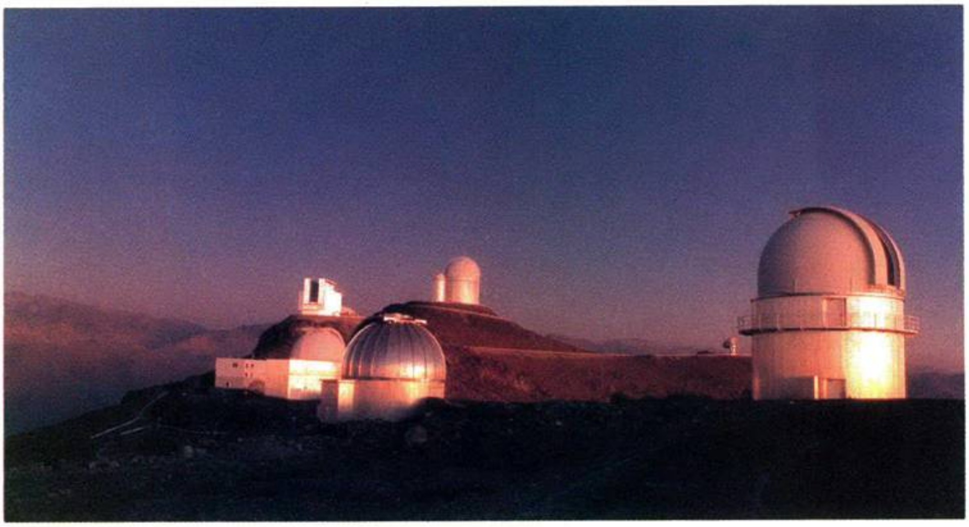
When I finally reached the top of the mountain, however, these negative thoughts began to fade and the main purpose of my visit rose to the fore. I was after the newest, most heralded addition to ESO's collection of "big glass" on the mountain: the New Technology Telescope (NTT). My guide and host was the famous Danish astronomer and comet discoverer, Richard West. In short order, he demonstrated why ESO is the leading astronomical center for southern sky research projects. Inside 15 minutes, he provided an in-depth, behind the scenes look at the NTT and how it came to be at La Silla, all the while switching casually among five languages that he speaks fluently.

How It All Started

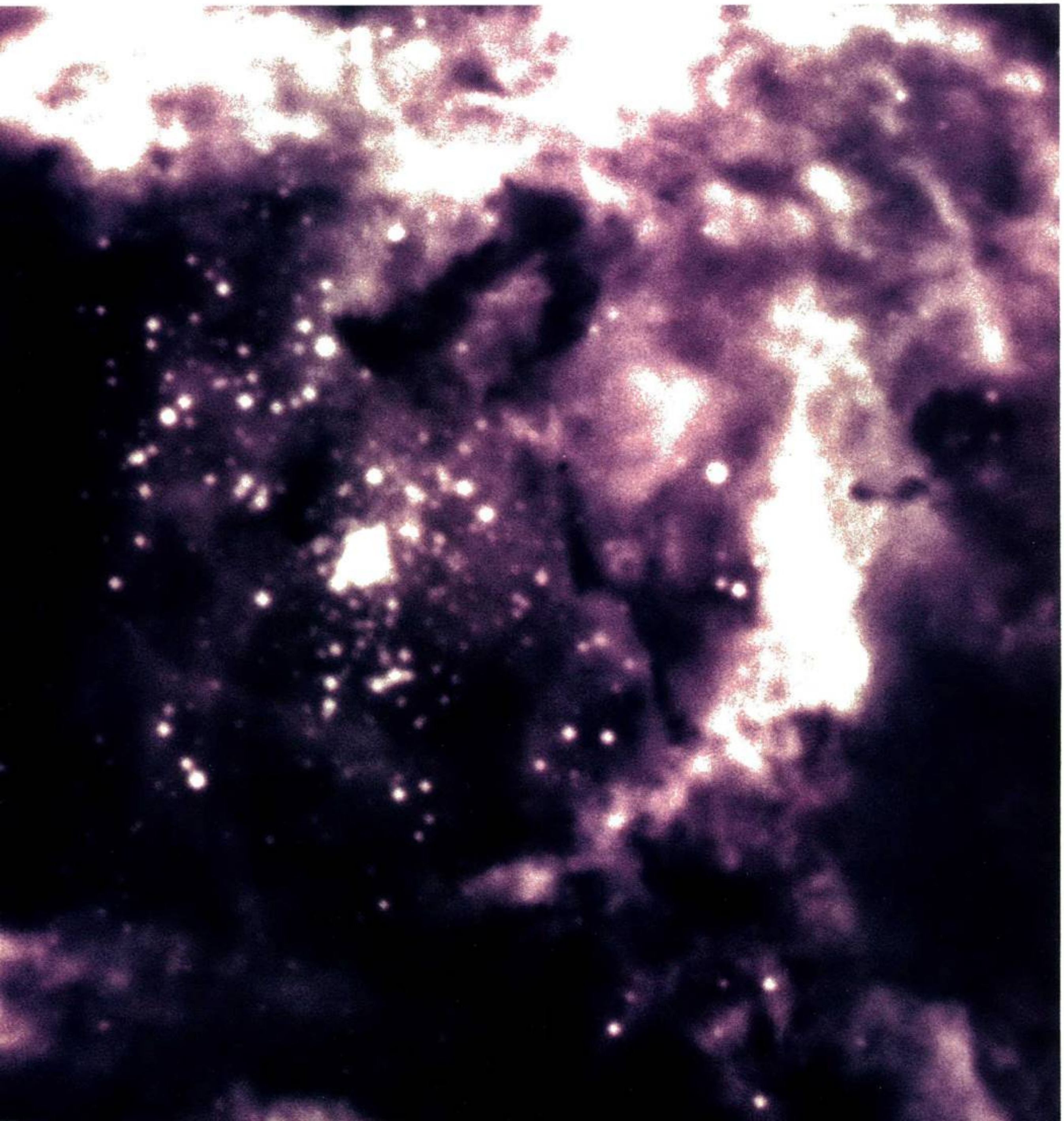
The NTT began life nearly 11 years ago. At that time it was just a concept, but ESO scientists were convinced that it represented the next logical stage in

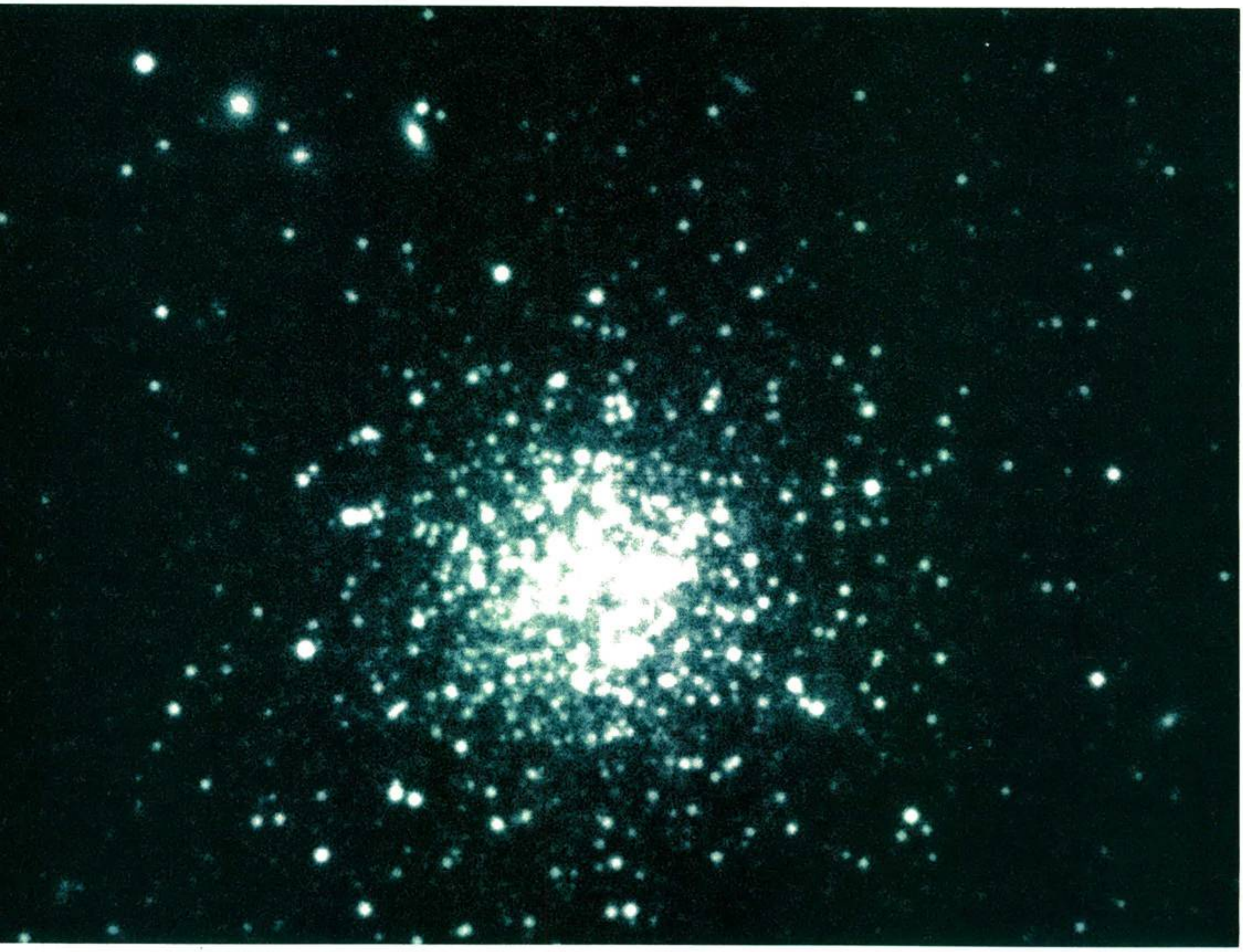
HOT, YOUNG STARS EXCITE dense clouds of gas and dust at the heart of the Tarantula Nebula in the Large Magellanic Cloud. The New Technology Telescope recorded this image in 60 seconds. ESO photo.

SHARP VIEWS of the cosmos are possible with the NTT because a system of 78 supports (left) actively keeps the mirror at its optimum shape. ESO photo.



ANOTHER CLEAR NIGHT awaits observers at the European Southern Observatory's La Silla facility. The NTT is the octagonal structure at the back left. Photo by Joel Harris.





optical telescope design. With typical ESO efficiency, the idea grew rapidly into reality.

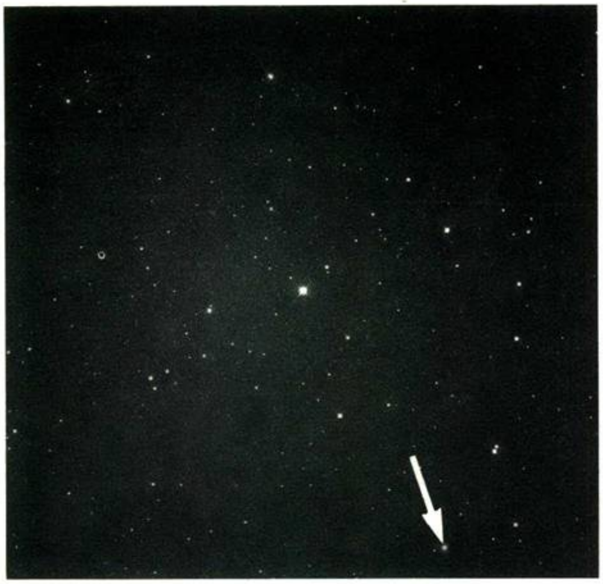
"One advantage we have at ESO in contrast to NASA and other institutions in the United States is that we plan and fully budget our future projects five years in advance, not on a year-by-year basis," says West. "Also, we do not have to persuade any governmental body similar to your Congress that a particular program ought to be funded. We simply come to an agreement and budget the necessary resources. This truly saves much unproductive time and energy."

ESO is a consortium of eight nations — Belgium, Denmark, France, West Germany, Italy, the Netherlands, Sweden, and Switzerland — that was founded in 1962 with the objective of providing a new observatory in the Southern Hemisphere for European astronomers. ESO's main headquarters are located in the West German city of Garching bei München. The European offices employ about 180 staff, associates, and astronomers, while the La Silla facility has 40 staff technicians and 150 local staff astronomers and assistants. Although the actual observations are made at La Silla in Chile, the data reduction, instrument design, and scientific and administrative tasks are executed back in West Germany.

La Silla is home to 14 optical telescopes, eight of which are one meter or larger in aperture. La Silla also boasts a 15-meter-diameter radio telescope that studies the heavens at submillimeter wavelengths. In addition to the mountaintop facility, La Silla encompasses an additional 800 square kilometers surrounding the summit. The purpose of these extended grounds is to preserve the integrity and quality of the observatory from such disruptive pursuits as local mining activities. And La Silla deserves preservation. The site proudly claims over 300 clear nights every year, low humidity, no light pollution from large cities, and average seeing of 0.88 arcsecond!

In 1983, after Italy and Switzerland joined the observatory consortium and thus assured the NTT's financial security, ESO conducted an engineering study for the new telescope. The Zerodur blank for the telescope's 3.58-meter (141-inch) diameter mirror was cast the next year. Concurrently, engineers at ESO completed the design of the telescope structure. By 1986 the building design was finished and the mirror blank transferred to the optical contractor for figuring.

The following year, the telescope was erected and tested in Europe. The unique rotating building that was to house the new telescope was fabricated and packed in containers. Meanwhile at La Silla, construction began on the service road and ramps, foundation, and annex portion of the NTT. In 1988, the telescope structure was taken apart and transported to Chile. That



THE NTT REVEALS STARS to the core of a globular cluster in the Fornax Dwarf Galaxy (left). ESO photo. The faint cluster lies at the lower right (arrow) at the bottom of this USNO photo of the galaxy (above).

same year, the rotating building arrived on the mountain and was assembled. May 1988 brought the testing of the NTT's optical system, including the novel "active optics" system. The primary mirror arrived at La Silla on September 22, 1988, while the final building construction, mechanical and electronic hardware emplacement, software integration, and optical calibration operations rounded out the rest of the year.

After the mirror was aluminized in early 1989, the NTT experienced "first light" and began basic operations on March 23. Formal dedication of the facility was conducted almost one year later, on February 6, 1990.

As if the foregoing pace of construction weren't overwhelming enough, the financial accomplishments for the NTT project are simply unparalleled. Consider this synopsis from Richard West: "NTT cost ESO a total of approximately $25 million Deutsche marks (about $14 million U.S.). The project was finished on schedule, seven years from the start of construction. In addition, the actual money spent fell several million Deutsche marks *below* projected levels, so we had some money left over."

The NTT construction story proved so attractive that Italy is now starting to build a copy of the telescope in the Northern Hemisphere. ESO is happily providing the plans, engineering advice, and information to the Italians free of charge. Both Austria and Portugal are inquiring about membership in ESO and several eastern European countries have also made inquiries regarding participation.

What's So New about the NTT?

The New Technology Telescope is far from being the largest telescope in the world and will, in fact, be dwarfed by the Keck telescope on Mauna Kea when that scope is finished. Neither does the NTT have the high profile that the *Hubble Space Telescope* possesses as an orbiting observatory. So what's so special about this particular piece of hardware? There are four fundamental advances in technology that make the NTT stand alone and unmatched.

First, the NTT utilizes a relatively thin primary mirror design, only 24 centimeters (9.5 inches) thick, coupled with an "active optics" system that analyzes stellar images about once every second and sends signals to the mirror supports to concentrate 80 percent of a star's light within an area of 0.125 arcsecond^2! This advancement yields a three-fold image improvement over any other ground-based telescope of similar aperture.

Second, the NTT uses an altazimuth mounting. Coupled with the lightweight 6-ton primary mirror, the total structure weighs a relatively small 110 tons. The entire structure rests on thermally-controlled, low-friction, oil film bearings that are 0.03 millimeters thick. The ambient fluid temperature varies by no more than about 0.1° Celsius to prevent any thermal interference while making observations.

Third, the NTT can be controlled remotely from ESO's headquarters in West Germany. This eliminates the need for an investigator to take the time and precious financial resources to fly to Chile to conduct an observing run.

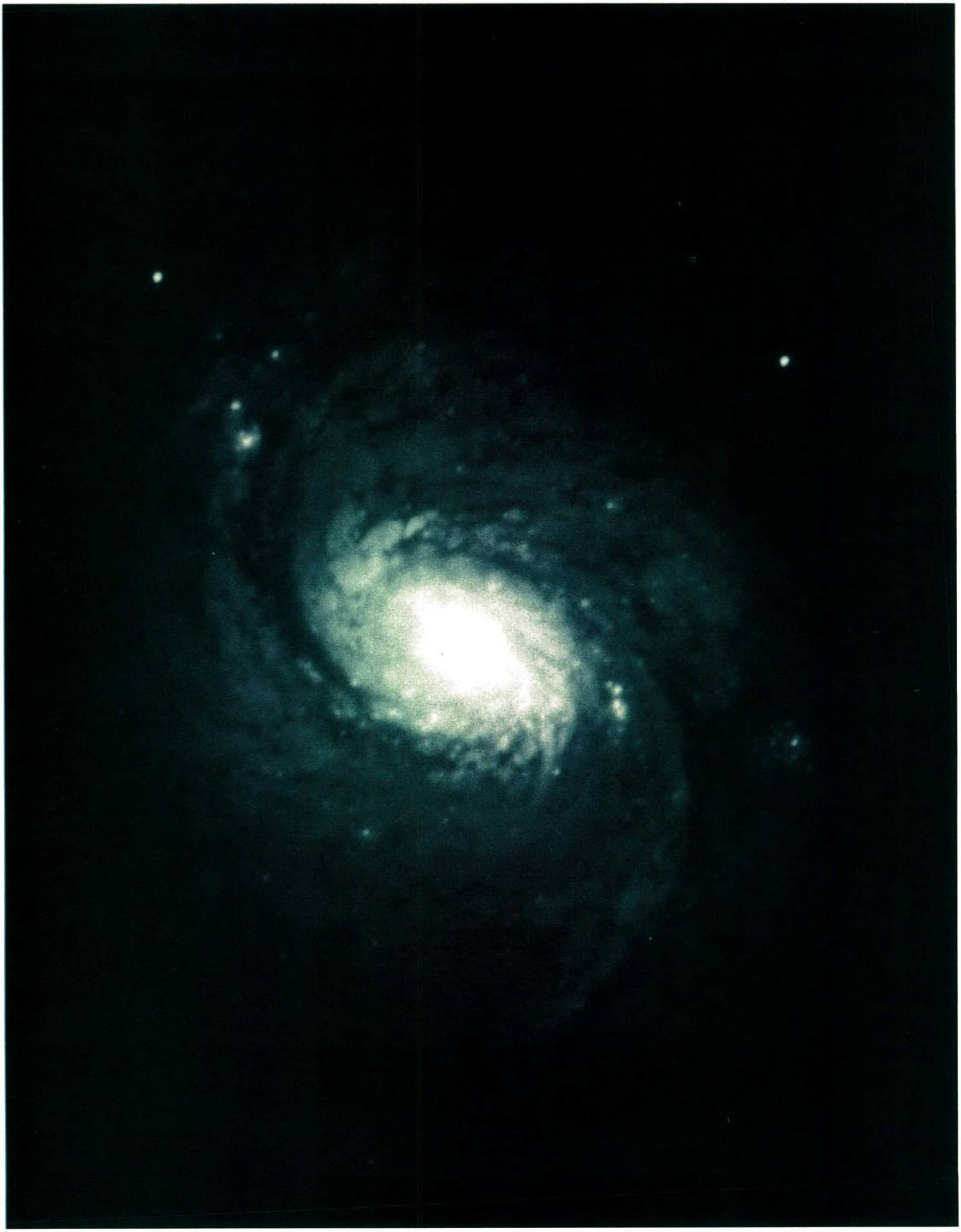
Finally, the NTT is housed in a unique building that virtually eliminates the traditional nemesis of "dome seeing" — disruption of observations due to thermal heating within the telescope housing itself. The NTT building is an octagonal structure that rotates 360° in azimuth, providing access to the entire sky. The building also has large openings and louvers in front and back to permit external air to flow readily through the housing and a windscreen to allow observations in winds up to 70 kilometers per hour (nearly 45 miles per hour). (See the photo on page 49.) Furthermore, fresh air circulates over the primary mirror constantly, further assuring thermal stability. In addition, the electronics equipment and guiding motors are chilled and the entire building is air conditioned.

Not satisfied with the advances already cited, ESO plans to upgrade the active optics feature of the NTT in a short time with what they term an "adaptive optics" system. The adaptive optics system uses a small, deformable mirror placed in front of the detector. Seeing effects are monitored continually and a computer responds to this information by rapidly moving the deformable mirror to effectively cancel out the problem. Tests with the ESO 3.6-meter telescope have already been conducted with adaptive optics. When studying objects at infrared wavelengths, the instrument's diffraction limit of approximately 0.18 arcsecond was reached directly. "The system works like a beauty," reports West.

Initial Results

The night I was on the mountain, Richard West and I paid a visit to the NTT around 11:30 p.m. In the prior 48 hours, the instrument had imaged Comet Halley at 25th magnitude, taken numerous spectra of powerful radio galaxies, and was looking to do more. West summed up a few of the performance characteristics of the NTT:

"When we imaged Comet Halley with the NTT, we noted some brightening over a few nights from a magnitude of 25 to about 23rd magnitude. From the signature of the light curve and the fact that *Giotto* and the



Vega spacecraft were never able to fix the rotation rate of the nucleus, we think the nucleus is still active, even at about 12 AU from the Sun."

West casually went on to comment that: "Routinely, we get arcsecond or better seeing with the NTT. On the average, we can typically image a 24th or 25th magnitude object in 5 to 10 minutes, given subarcsecond seeing conditions."

Some dramatic photographic results are included on the pages of this article. Most notable is the image on page 46 of a 23rd-magnitude globular cluster in the Fornax Dwarf galaxy, a faint member of the Local Group. This particular image was taken by visiting Australian astronomer Brian Jarvis on December 3, 1989, using a CCD camera on the NTT. The exposure was 5 minutes long and the seeing 0.48 arcsecond. The field of view covers a region about 77 by 100 arcseconds. Note that individual stellar images are resolved down to the core of the cluster itself. To gain a fuller appreciation of the faintness and minuteness of this object, look at the Schmidt camera photograph of the entire dwarf galaxy on page 47 and locate Cluster #2 at the lower right. Then remember that this galaxy is 700,000 light-years away from our own!

Another impressive image is of the strong radio galaxy M77 (NGC 1068) in the constellation Cetus, which is located about 55 million light-years from us. This Seyfert-class galaxy seems to contain clouds of interstellar gas in rapid motion, possibly around a huge black hole located at the middle of the galaxy. The image shown at left was taken December 31, 1989, by observer Jorge Melnick, and was a 2-minute exposure. Seeing was 0.68 arcsecond and the image field is 150 by 115 arcseconds.

In little over a year, images like these are creating a groundswell of reaction in the global astronomical community. Following the publication of early photographic results, ESO experienced a five-fold oversubscription rate for observing time on the NTT.

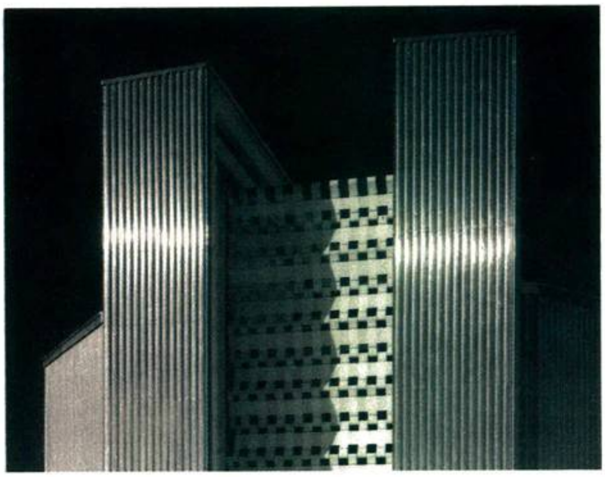
NTT's Future Projects

When asked what the next 6 to 12 months holds in store for the NTT, West described four major areas of investigation that ESO astronomers will be concentrating on. First is a continuation of their investigations of important extragalactic objects, including the Magellanic Clouds, the Sculptor Group of galaxies, and faint members of the Fornax galaxy cluster. Specific targets include individual stars in the LMC and SMC and Cepheid variables down to about 27th magnitude. Faint globular clusters will also be studied in greater detail than previously.

Second, several extragalactic radio sources will be observed. The NTT will concentrate specifically upon those Seyfert-class galaxies with particularly high noise activity. Also, galaxies with redshifts of 1.4 and higher will be of special interest, as the NTT will be striving to catalogue and increase the known number of these objects.

Third, further studies of gravitational lensing objects will be conducted. These objects are typically massive galaxy clusters whose gravity acts like a giant lens to bend light coming from more distant galaxies or quasars. One new lensing object has already been discovered by the NTT and there are unquestionably more of them out there. The NTT will also seek to find not just relatively nearby lensing objects, but very distant ones too.

THE BRIGHT NUCLEUS of the Seyfert galaxy M77 shines intensely in this NTT image. Such active galaxies may reveal their secrets to the NTT's acute eye. ESO photo.



SHIELDED FROM HIGH WINDS by a windscreen, the NTT remains stable and can continue to make observations even in gusts up to 45 miles per hour. ESO photo.

Fourth, the NTT will be turned inward to the familiar objects in our solar system — the planets. When local seeing conditions are about 0.4 arcsecond, the NTT will observe many of the outer gas giant worlds with *Voyager*-like resolution. Coupled with an effective CCD shutter capability of 1/1000 second, the NTT will be able to study the changing appearances of many members of our planetary family.

The future thus looks especially rosy for the NTT. It's easy to understand why Richard West and his colleagues at ESO are very proud of this new addition to the existing "stable" of optical instruments at La Silla. In the coming months, look for more dramatic results from this exceptional piece of equipment. But don't think ESO is stopping here. Another project, the Very Large Telescope, is already in its initial design and site location phase. When finished, the Very Large Telescope will consist of four 8-meter, NTT-style telescopes that will effectively be arrayed together to yield an instrument equivalent to a 16-meter telescope. ESO received the administrative go-ahead in late 1987, and the target date for completing the first instrument is 1995. The entire array is planned for completion by 1998. Given the rapid development and early successes of the New Technology Telescope, the prospects for La Silla appear as bright as one of the telescope's CCD images. □

Joel K. Harris is director of Twilight Tours, a science and astronomical expedition organizing company based in Burbank, California. His previous article, "Return to A New World," appeared in the April issue. The author especially wishes to thank Richard West of ESO and John Sanford of the Orange County Astronomers for their help with the images used in this article.

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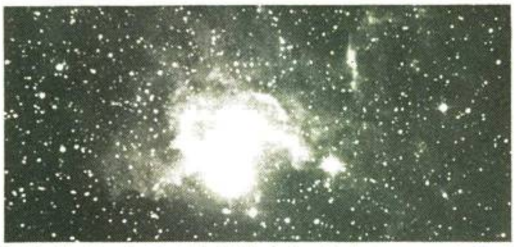

IC 405, "The Flaming Star Nebula," in Auriga. 45 minute exposure by Martin Germano using an 8" f/5 telescope with LUMICON 2" Newtonian EASY-GUIDER, and 2415 film hypersensitized in a LUMICON Model 300 Hyper-Kit. IC 405 is faint and is seen best visually with either a LUMICON UHCFilter, or preferably a LUMICON H-Beta Filter.

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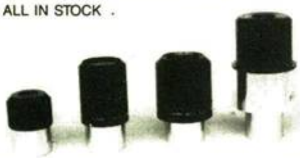

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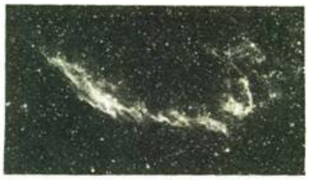

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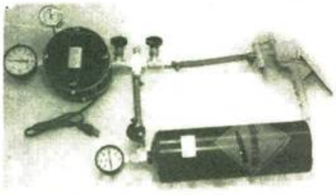

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For any alt-azimuth (Dobsonian) scope	$589

LUMICON NGC SKY VECTOR™. Has same features as the LUMICON SKY VECTOR II™ but has all 7730 revised NGC objects in memory. Includes IDENTIFY function to provide identification of nearest NGC object.

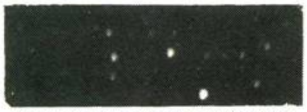
NGC SKY VECTOR™ for C-8, C-11	$750
For Meade 2080, Meade 2120	$750
For Coulter Odyssey 8",10",13",17½"	$750
For C-14 (rewire dec. motor)	$825

The **LUMICON SKY VECTOR II™** has all the features of the regular SKY VECTOR, but has 1000 of the best deep-sky objects in memory, selected by noted observer Steve Gottlieb, along with their coordinates, size, magnitude, and other descriptive data. The sophisticated computer programming also will guide you to the object selected by displaying the real-time angular separation. Just move the telescope until the angles displayed become "0" using the "GUIDE" mode.

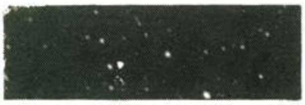
LUMICON SKY VECTOR II FEATURES:

- All 110 Messier objects
- Brightest 31 alignment stars
- User definable catalogue of 25 objects retained in memory without power.
- 430 galaxies, groups & clusters
- 137 best open star clusters
- 133 best planetary nebulae
- 59 emission & reflection nebulae
- 8 best dark nebulae
- 84 best gobular star clusters
- Includes object visual magnitudes, a feature missing from competing systems
- 149 best colored & multiple stars
- ROM upgradable for planets, extended object lists, etc.
- TIMER function, elapsed time & stop watch
- 2 star alignment for alt-azimuth or equatorial telescope systems
- 1 star alignment if polar aligned
- Uses Epoch 2000.0 coordinates
- May align on any of the 1000 objects in memory

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5



Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener Lens	$285.00
LUMICON 2" EASY-GUIDER	$169.50
2" EASY-GUIDER (Mamiya 645)	$199.50
2" Adapter for Pentax 6x7	$85.00
2" Adapter for Hasselblad	$185.00
2" Adapter for Bronica SQ-A	$175.00
2" Extension for viewing	$26.00

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(415) 447-9570
FAX (415) 447-9589

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All Meade Premier Series telescopes **include Smart Drive (SD) permanent periodic error correction**, multi-coated enhanced optics (MCOG) and **include** advanced LX6 all-electronic drive system. Select f/10 or f/6 optics, and select only the optional features you **need.** The 8" has an 6X30 finderscope and the 10" has an 8X50 finderscope. SD = Smart Drive, SP = Special Promotion.

2080 Model 30SD, 8" f/10	$1495
2080 Model 36SD, 8" f/6	$1695
2120 Model 30SD, 10" f/10	$1895
2120 Model 30SP, 10" f/10	$1599
2120 Model 36SP, 10" f/6	$1699
Model 2600 16" f/10	$9950
LX6 Smart Drive upgrade	$299

Options Enhance Performance

Super Wedge for 10"	Add $240
ECC Electronic Command Center	$275
#39 Declination motor	Add $109
Digital setting circle	Add $399
2" Star diagonal	Add $179
LUMICON Cassegrain Easy-Guider *(Please specify camera)*	Add $225
LUMICON Giant Easy-Guider (for #30) *(Specify camera)*	Add $395
LUMICON Giant Easy-Guider (for #36) *(Specify camera)*	Add $295

PREMIER 2080
MODEL 50SD
$1795

Meade Premier 2080 Model 50SD

MEADE SERIES 4000 EYEPIECES

Super Plossl: 6.4mm, 9.7mm, 12.4mm **$89** 15mm, 20mm, 26mm **$89;** 32mm **$109**
Super Wide-angle: 13.8mm **$129,** 18mm **$135,** 24.5mm **$149,** 32mm (2") **$219**
Ultra Wide-angle: 4.7mm **$149,** 6.7mm **$179,** 8.8mm **$209,** 14mm **$249**

SCHMIDT-CASSEGRAIN

2045D 4" f/10 w/motor drive	$695
2080A Standard 8" f/10 w/tripod	$999
2080B Std. w/tripod, MCOG	$1058
2080 Model 50SD, 8" f/10	$1795
2120 Model 50SD, 10" f/10	$2295
2120 Model 50SDH, 10" f/10 w/Super Wedge, Smart Drive	$2535
2080 Model 56SD, 8" f/6.3	$1995
2120 Model 56SD, 10" f/6.3	$2495
2120 Model 56SDH, 10" f/6.3 w/Super Wedge, Smart Drive	$2735
Dew shield - essential! 8" **$65;** 10"	$98
LUMICON EASY-GUIDER for 2080	$225
EASY-GUIDER (f/4-f/10) for 2120	$395
CAT command control, 8200 objects	$999

SCHMIDT-NEWTONIAN

MTS-SN6, 6" f/5, #788 drive	$649
MTS-SN6 w/drive, MCOG	$698
MTS-SN8, 8" f/4 w/drive, MCOG	$795
MTS-SN8, 8" f/4 w/LX3 drive, MCOG	$1048
#36 LX3 hand cntrl. & #38 dec. motor	$189

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Model 826C 8" f/6 w/motor, 2" focuser	$898
SPECIAL PROMOTION	
Model DS-10A, 10" f/4.5 with motor, 2" focuser	$775
Model DS-16AB, 16" f/4.5 w/motor, 2" focuser, Sealmaster ball bearings	$1875
8X50mm finderscope w/brackets for DS-10 or DS-16	$109

1.8x MULTIPLIER LENS

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. Guide-stars also become much sharper to make guiding easier. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.8x multiplier lens	$235.00

NEW! LOW PROFILE HELICAL FOCUSERS

FROM
$49.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	$49.50
LUMICON 2" Helical Focuser 1½" high	$59.50
LUMICON Non-rotating Helical Focuser	$89.50
2" rack & pinion focuser, only 2" high	$139.00
3 handles for non-rotating focuser	$12.95
2"/1¼" **adapter** w/48mm filter threads	$20.00
2" LUMICON EASY-GUIDER	$169.50

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra. The

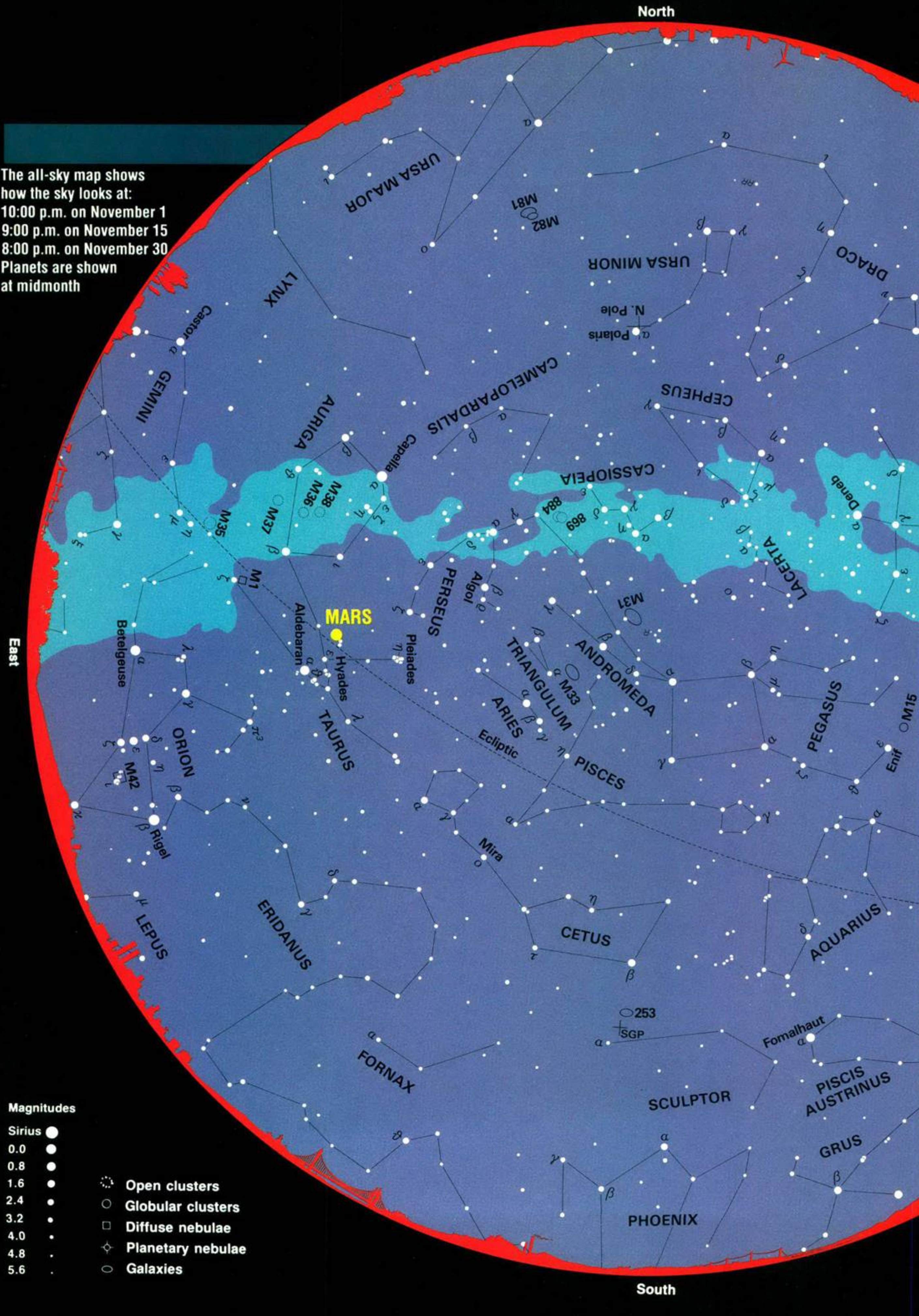
1¼" 50mm Finderscope **$59.50**, right-angle	$89.50
1¼" straight-thru 80mm SUPER-FINDER	$169
1¼" right-angle 80mm SUPER-FINDER*	$179.50
1¼" right-angle version, w/star diagonal	$209
25mm Cross-hair 1¼" eyepiece (12X)	$29
*1¼" Star Diagonal **$32**, 2" Star Diagonal,	$159
1¼" Amici Prism diag. for correct left-right views	$69.50

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

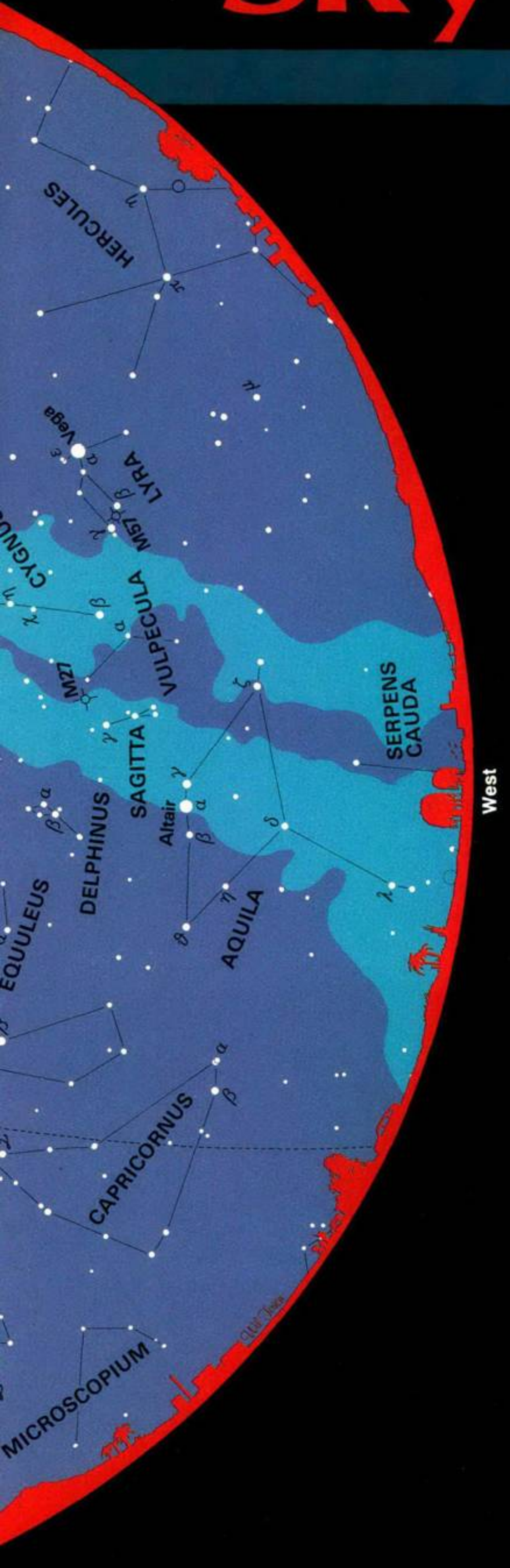
2" adapter for C-8, Meade 2080, etc.	$26.00
2" adapter for C-80, C-100 refractor	$39.50
2" adapter for C-70, C-80F, C-90F, C-100F	$39.50
2" Accessory adapter for Comet Catcher*, C-6*, Meade 310, 320 refractor	$30.00
2" adapter for Takahashi E-130, 160	$59.50

The all-sky map shows how the sky looks at:
10:00 p.m. on November 1
9:00 p.m. on November 15
8:00 p.m. on November 30
Planets are shown at midmonth


North
East
South
URSA MAJOR
M81
M82
URSA MINOR
DRACO
N. Pole
Polaris
LYNX
CAMELOPARDALIS
CEPHEUS
Castor
GEMINI
AURIGA
Capella
M38
M36
M37
M35
M1
CASSIOPEIA
884
869
Deneb
LACERTA
PERSEUS
Algol
M31
MARS
Aldebaran
Hyades
Pleiades
Betelgeuse
ANDROMEDA
TRIANGULUM
M33
ARIES
TAURUS
ORION
M42
Rigel
Ecliptic
PISCES
PEGASUS
M15
Enif
Mira
CETUS
AQUARIUS
LEPUS
ERIDANUS
253
SGP
Fomalhaut
FORNAX
SCULPTOR
PISCIS AUSTRINUS
GRUS
PHOENIX
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

November 1990



MARS AT ITS BEST

On November 27, when Mars reaches opposition, it is at its brightest for the year and visible in our sky all night long. The –2.0-magnitude planet also presents its largest disk of the year in November, providing telescopic observers with an excellent view of Martian surface features.

JUPITER BRIGHT IN THE MORNING

Jupiter is even brighter than Mars in November, shining at magnitude –2.2 high in the morning sky. Naked-eye observers should watch the Moon pass near Jupiter on the night of November 8/9, while telescopic observers can watch the beginning of a series of mutual events among the giant planet's Galilean satellites.

LEONIDS PEAK ON NOVEMBER 17

The predawn sky on November 17 will be the scene of many bright, colorful, and fast-moving meteors as the Leonid meteor shower reaches its peak. An attentive observer can expect to see up to twenty meteors per hour in the moonless sky that morning and lesser numbers on the morning before and after.

Calendar of Events

1 Venus is in superior conjunction

2 Full Moon is at 4:48 p.m. EST

3 The Moon is at perigee (222,840 miles from Earth), 6:09 p.m. EST

4 The Moon passes 3° north of Mars, 9 p.m. EST

7 Sappho is at opposition

9 The Moon passes 1.6° south of Jupiter, 2 a.m. EST
Last Quarter Moon is at 8:02 a.m. EST

10 Pluto is in conjunction with the Sun

13 Mars passes 6° north of Aldebaran, 5 a.m. EST

15 Vesta is at opposition

17 New Moon is at 4:05 a.m. EST
Leonid meteor shower peaks

18 The Moon passes 0.7° north of Antares, 10 a.m. EST
The Moon passes 1.7° south of Mercury, 3 p.m. EST
The Moon is at apogee (252,606 miles from Earth), 9:57 p.m. EST

19 Mars is closest to Earth (48 million miles away)

21 The Moon passes 0.6° south of Saturn, 11 p.m. EST

25 First Quarter Moon is at 8:11 a.m. EST

27 Mars is at opposition

30 Jupiter is stationary

Eye on the Sky by Deborah Byrd

A RUDDY BEACON SHINES ALL NIGHT

Our neighbor Mars shines brighter this month than it has in over two years. The Red Planet comes to opposition on November 27, when Earth passes between Mars and the Sun. Just a week before that, Mars is at its closest to us for the year, around 48 million miles away. For planets, and especially for Mars, extra closeness to Earth means they appear extra bright in our sky. And Mars is definitely bright! At magnitude –2.0, it outshines all the stars and is bettered only by Jupiter among the visible planets.

In early November, you'll find Mars rising in the northeast as evening twilight fades into nighttime. By the end of the month, it comes over the horizon at sunset, wheels slowly across the sky during the night, and sets at sunrise. Mars appears in the constellation Taurus, whose brightest star, Aldebaran, also shines with a reddish hue. At magnitude 0.9, Aldebaran is much fainter than Mars.

Although Mars reaches opposition once every two years, the character of each opposition varies significantly. The best opposition of Mars in recent memory was two years ago. This year, the Red Planet is 32 percent farther away than it was in 1988. Yet for Northern Hemisphere observers, the 1990 apparition nearly rivals that of 1988 because Mars is much higher in the sky. When the planet crosses your local meridian around midnight this month, it is a whopping 25° higher than it was during the best observing time in 1988.

This is an excellent opposition for Mars, by far the best we'll see during the remainder of the twentieth century. The planet is now so bright and fiery red that it's bound to stir your imagination, if not capture your heart.

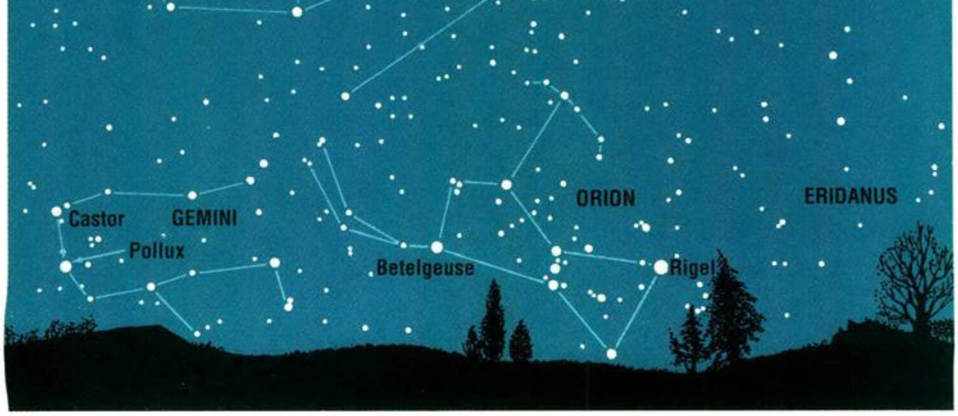
METEORS FROM THE LION'S HEAD

Meteor showers offer a strange combination to sky watchers: they're easy to view but they can be quite frustrating also. Anybody can watch for meteors if they pick an observing site away from city lights and have a blanket or lawn chair to lie on while gazing up at the sky. What's difficult about meteor watching is waiting for the meteors! Sometimes they appear in great numbers and sometimes they don't.

The Leonid meteor shower, an annual shower that peaks this year on November 17, provides a good example of the fickle nature of meteor showers. This legendary shower is quite sparse in most years, but astoundingly rich at intervals of 33 years.

The secret to the split personality of some showers stems from the origin of the meteors. Meteors in annual showers are spawned by comets orbiting the Sun. The Leonids come from Comet Tempel-Tuttle, whose orbit carries it near the Sun — you guessed it — every 33 years. A large swarm of Leonid meteors apparently follows close behind Tempel-Tuttle. When the comet is nearby, there can be a fabulous Leonid meteor storm.

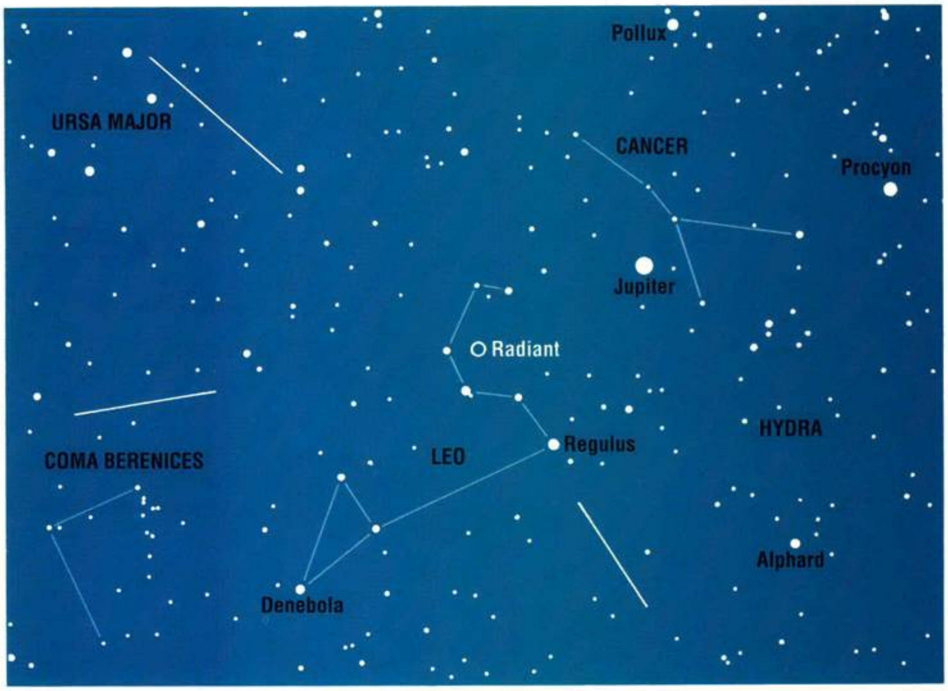
MARS SHINES BRILLIANTLY throughout November, but it is brightest on November 27 when at opposition. Look for the Red Planet in the eastern sky during the early evening hours.



That was the case in 1966, when observers on the West Coast reported seeing more than 100 Leonid meteors per *second*. That's a far cry from this year's predicted rate of 5 to 20 meteors per hour. However, this year's shower is blessed by the absence of the Moon, which is new on the 17th.

The Leonids are fun to watch. They are typically bright, often green or blue in color, and about half leave faint, glowing trails that last up to several minutes. They are the swiftest of all meteors, plunging into our atmosphere at 44 miles per second. They appear to radiate from the Sickle asterism in Leo the Lion, but they can streak across any part of the sky.

The best time to view the Leonids is before dawn on the morning of November 17, though the shower should be pretty good on the morning of the 18th also. For your observing location, choose an open area with little or no light pollution and a good view of all parts of the sky. Also dress warmly, bring along something warm to drink, and get up and move around occasionally to keep warm.



STREAKS OF LIGHT will play across the predawn sky on the morning of November 17. These streaks are Leonid meteors, and you can expect to see from five to twenty of them an hour.

NOVEMBER'S PLANETS

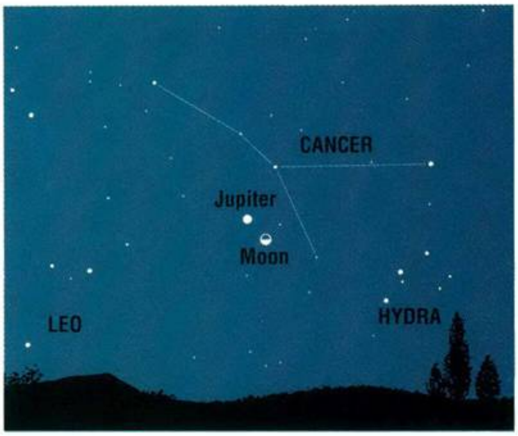
Saturn can be found in the southwest each evening, among the stars of the constellation Sagittarius. At magnitude 0.6, it is now a fainter version of the bold, golden planet it was last summer. Saturn still can charm us, however. It looks very pretty near the waxing crescent Moon on the evening of November 21.

As Saturn has faded over the past few months, Mars has grown rapidly brighter, a trend continuing for most of November. The Red Planet shines at magnitude –1.6 at the beginning of the month and brightens to magnitude –2.0 by opposition on November 27. Then the trend stops. When December begins, Mars will already be fading.

Mars remains in Taurus this month, near the bright orange-colored star, Aldebaran. The two appear side by side after nightfall early in the month. Look for the pair on the evening of November 4, when the nearly Full Moon passes by. By month's end, Mars has moved westward to a location between two famous star clusters: the cluster to which Aldebaran appears to belong, the Hyades, and the tiny dipper-shaped cluster known as the Pleiades.

The next planet to appear is mighty Jupiter, which nearly steals the show from Mars this month. Rising over the east-northeastern horizon shortly before midnight, Jupiter is a glorious sight. The giant planet shines at magnitude –2.1 on November 1, brighter even than Mars at opposition, and it brightens to magnitude –2.3 by month's end. These two planets offer an interesting visual contrast too, with Jupiter appearing creamy white in color compared with the ruddy hue of Mars.

But the highlight of Jupiter's month comes on the night of November 8/9, when the planet lies near the Last Quarter Moon. Jupiter then lies in Cancer, as it does all month, not far from the Beehive star cluster.



JUPITER AND THE MOON make a pretty pair on the night of November 8/9. The Last Quarter Moon passes about 2° south of the bright planet not long after they both rise in the late evening.

Mercury appears very low in the southwest shortly after sunset during the last week of November. It will reach greatest elongation from the Sun in early December, though this is not a particularly favorable apparition for Northern Hemisphere observers.

Venus is at superior conjunction, directly behind the Sun, on November 1. Our brightest planet is thus lost in the Sun's glare all month; it will return to view low in the evening sky in mid-December.

NOVEMBER'S STARRY SKY

To the south and east of the prominent Great Square of Pegasus is the inconspicuous zodiacal constellation, Pisces the Fishes. Use the waxing gibbous Moon as a guide to locate it on the evenings of November 26-28; however, your best view will come on a moonless night from a location far removed from city lights.

Pisces is a large constellation comprised mostly of faint stars. Even its brightest stars shine at only 4th and 5th magnitude. The constellation consists of two "streams" of stars that join below the southeastern corner of the Great Square so that they form a graceful letter V. In old star atlases, each side of the V is pictured as a fish, called the Northern and Western Fish. The fish are often shown tied together with a ribbon through their tails.

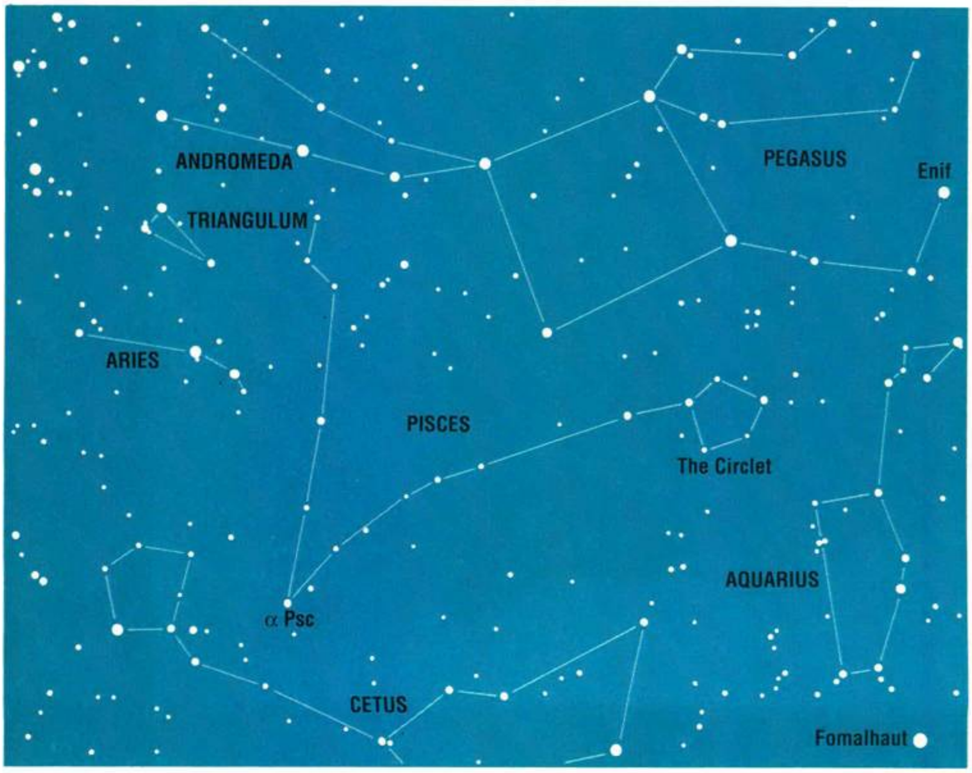
The Northern Fish, which is located east of the Great Square, is somewhat less distinguished than its brother. That's because the Western Fish contains an asterism — an easily recognizable pattern of stars — called the Circlet. The Circlet, which represents the open mouth of the fish, is easier to see than the rest of the constellation.

My favorite star in Pisces, however, is the one at the tip of the V, where the two fish supposedly are joined together. This is Alpha (α) Piscium, otherwise known as Al Rischa from an Arabic word meaning "the cord."

Al Rischa shines at magnitude 3.8. This star is a telescopic double that is becoming harder to split, or resolve, with each passing year. It consists of two suns that take an estimated 930 years to complete a single orbit about one another. They have been drawing closer together since the 1600s and should appear closest about a century from now. When gazing at Al Rischa with the eye alone, I like to imagine the two mighty stars in this one shining point and the dance of their long mutual orbit.

In Greek mythology, Pisces originated in a simple stroll down a riverbank by two gods, Venus — the goddess of love — and her son, Cupid. Mother and son were startled by the giant Typhon, and in a panic, they leapt into the river and transformed themselves into fish. The other gods enjoyed this performance so much that they later transported the fish to the heavens. □

THE TWO FISH OF PISCES lie high in the southeastern sky on November evenings. This relatively inconspicuous zodiacal constellation can be found below and to the left of the Great Square of Pegasus.



Deborah Byrd is the creator, writer, and producer of "Star Date," an independently syndicated daily radio series on commercial and public radio.

THE RED PLANET REVEALS ALL

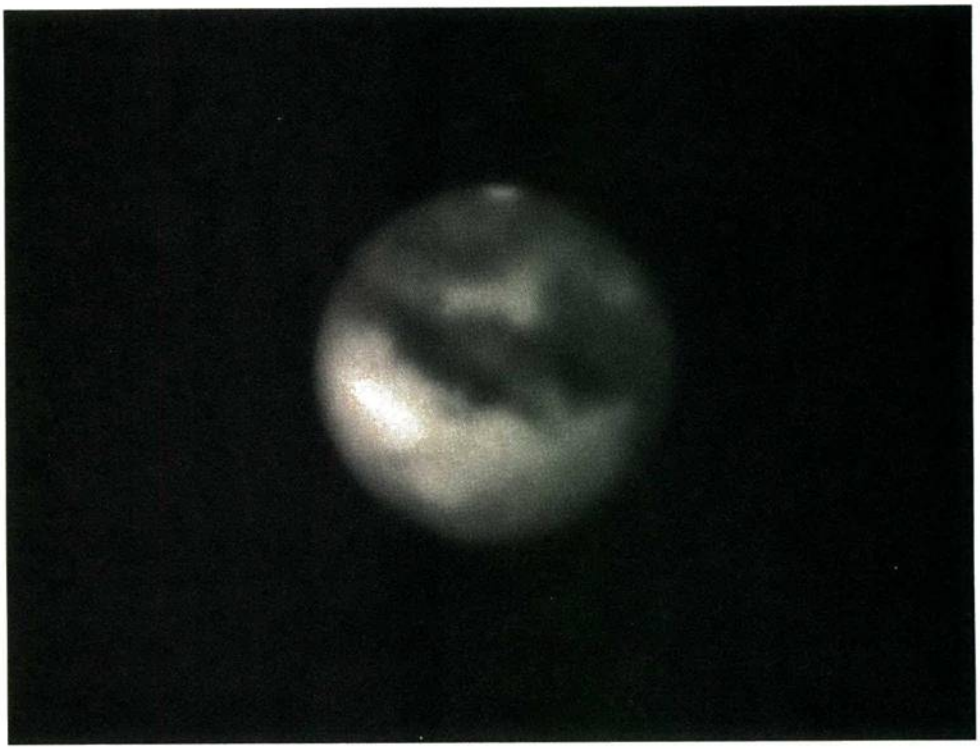
Two important milestones occur for Mars this month. The first comes on November 19/20, when Mars makes its closest approach to Earth during this apparition. When Mars is close it looms large in the eyepiece (18.1" across in this case), and the larger Mars appears, the easier it is to see details on its surface.

The second milestone occurs a week later, on November 27, when Mars reaches opposition. On that night the Red Planet rises at sunset and sets at sunrise, though it is above the horizon whenever the sky is completely dark through most of the month. These two factors make November the best time to view Mars in the past two years, and the planet won't appear as large and bright again until after the turn of the century. (For more details on the current apparition, see "Mars Shows Its Stuff" on page 66.)

Like many backyard astronomers, I often give friends, acquaintances, and even strangers a view of the sky through my telescopes. And more often than not, those people ask me to show them Mars. Most of the time, the best view I can give them is considerably less than awe-inspiring. There, swimming in a sea of heat waves, is a tiny ocher disk with perhaps a white cap. They may not say anything, but it's clear that most find their first view of the Red Planet a little disappointing.

Fortunately, the seeing conditions for observing Mars should be quite good at this year's opposition for observers at mid-northern latitudes. Mars lies along the northern part of the ecliptic, among the stars of Taurus, and thus spends a long time each night high in the sky where the seeing is generally best.

Even though we benefit from Mars' high declination, we still need to do all we can to maximize the local seeing conditions. The most important step is to pick a site that has a minimal number of heat sources to cause turbulence in the atmosphere above you. Avoid sites near asphalt parking lots, concrete buildings, and other similar objects that absorb the Sun's heat all day and then release it at night, just in time to ruin the seeing. (For more hints on viewing Mars, see "Ten Pointers for Mars Observers," July 1988.)



MARTIAN SURFACE FEATURES are easiest to see when Mars presents a large disk, as it did in 1988 when Donald C. Parker took this photo and as it does this month.

When viewing Mars, start with an eyepiece that gives an exit pupil of roughly 1 mm. (To determine the exit pupil, divide the aperture of your telescope in mm by the power you're using. For example, a 6-inch telescope has an aperture of approximately 150 mm, so a power of 150x gives an exit pupil of 1 mm.)

If the seeing permits, progressively increase the power until the last increase yields no improvement in the view; then drop back to the previous power. This power is probably the one at which you'll see the most detail. Increase the power again only if you notice the seeing grow steadier.

Examine the disk of Mars for a few minutes to give your eye time to get used to the view. To locate the main features visible on the Martian disk, use the map and guide to Martin central meridians found on page 71.

The dark gray features on the Martian surface are called "albedo features." In other words, these markings are regions where the surface material is less reflective (darker) than in surrounding regions. Unfortunately for earthbound observers, the markings do not correlate with actual geological features. The albedo features are mostly vast fields of dark lava swept bare of the ocher-colored sand by the fierce Martian winds.

To make the albedo features stand out more clearly, try viewing through an orange or light red filter. This brightens the orange-red planet and darkens the markings, enhancing the contrast. Filters also reduce the effect of irradiation, the tendency of light from very bright areas to "spill over" into darker areas. To demonstrate the effects of irradiation, look at Mars at a very low power and then change to a very high power. You'll probably notice that the south polar cap looks bigger in proportion to the rest of the disk in the low-power view than it does in the high-power view.

Suppose your view of Mars seems very clear and sharp and you've identified many, but not all, of the features the map leads you to expect to see. Further suppose that, in place of a feature you think should be easy to spot, you see a rather featureless yellowish patch. Don't despair — you're not lost. Instead, you're viewing that scourge of Mars observers, a dust storm. That's what is likely obscuring your view of the expected albedo feature.

The good news is that dust storms shouldn't pose a major problem. These storms have historically reached a maximum near or shortly after Mars' perihelion, which occurred this year on June 30. Thus, although it's not impossible that we'll see a heavy-duty dust storm this month, it's quite unlikely.

ACTION AMONG THE GALILEAN SATELLITES

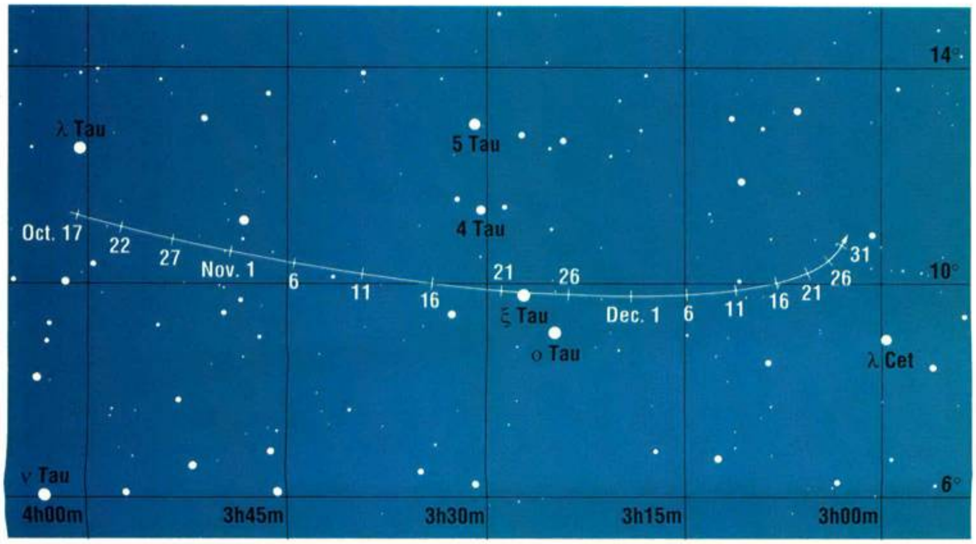
Jupiter now rises before midnight and is high in the sky by the time morning twilight begins. The giant planet, which measures 39" across in November, is worth watching this month for two reasons. First, it will be interesting to see whether the unusual activity seen in the Jovian atmosphere during the previous apparition, particularly the disappearance of the South Equatorial Belt, continues during the current apparition. No one is sure when the South Equatorial Belt will return or whether Jupiter has any other unexpected tricks up his sleeve.

One thing astronomers are sure about, however, is that another season of mutual eclipses, occultations, and transits among Jupiter's large satellites begins in November. Approximately every six years, the orbital plane of the Galilean satellites tilts edge-on to our line of sight. When that happens, the satellites sometimes pass in front of (or occult) one another, or pass through the shadow of another satellite and go into eclipse. The season of mutual events starts slowly (there are *only three this month), but by ear*ly 1991 they will be occurring about once a day.

COORDINATES FOR VESTA

Date	R.A. (2000)	Dec.
Oct. 17	3h58.1m	11°06'
Oct. 22	3h54.8m	10°52'
Oct. 27	3h50.9m	10°38'
Nov. 1	3h46.5m	10°24'
Nov. 6	3h41.7m	10°11'
Nov. 11	3h36.6m	9°59'
Nov. 16	3h31.3m	9°49'
Nov. 21	3h26.1m	9°41'
Nov. 26	3h21.1m	9°36'
Dec. 1	3h16.4m	9°34'
Dec. 6	3h12.1m	9°35'
Dec. 11	3h08.4m	9°39'
Dec. 16	3h05.3m	9°46'
Dec. 21	3h02.9m	9°57'
Dec. 26	3h01.2m	10°11'
Dec. 31	3h00.3m	10°28'

VESTA REACHES OPPOSITION on November 15, when it shines at magnitude 6.5 among the stars of Taurus. It remains an easy target for telescopes through the end of the year. Positions are shown at 11 p.m. EST (10 p.m. CST, 9 p.m. MST, and 8 p.m. PST).



MUTUAL EVENTS OF THE GALILEAN SATELLITES

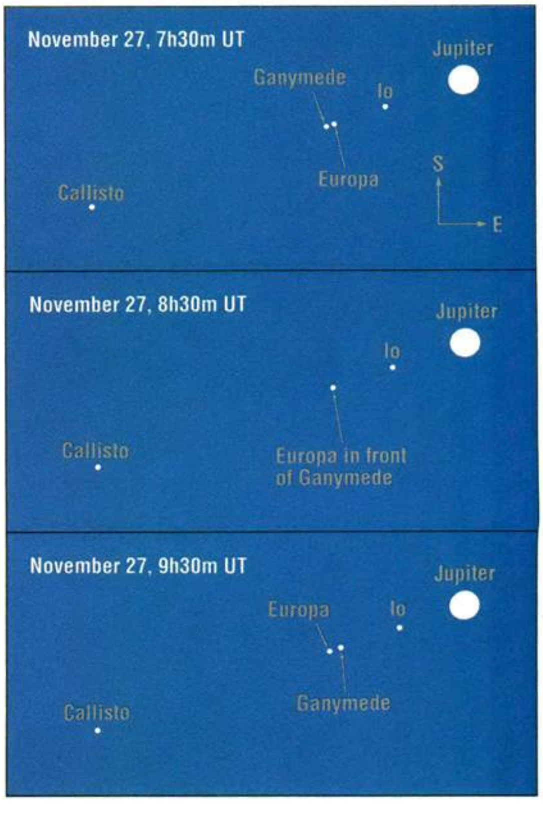
Date	Begin Time	End Time	Event	Type of Event	Diameter Covered	Light Loss
Nov. 13	1h43.9m	1h50.9m	Europa Occults Ganymede	Partial	21%	7%
Nov. 20	5h05.4 m	5h14.7m	Europa Occults Ganymede	Partial	41%	16%
Nov. 27	8h26.7m	8h38.0m	Europa Occults Ganymede	Partial	58%	23%

Begin Time: Universal time at beginning of event. (Subtract 5 hours to convert to EST, 6 hours for CST, 7 hours for MST, and 8 hours for PST.) **End Time:** Universal time at end of event. **Event:** The nature of the event and the satellites involved. **Type of Event:** Whether the event is partial, total, or annular. **Diameter Covered:** The percent of the second satellite's diameter occulted by the first satellite at midevent. **Light Loss:** The percent of light lost from the combined light of both satellites at midevent.

All three events this month are partial occultations of Ganymede by Europa (see the table at right). The best event for North American observers is the last one, occurring on the morning of November 27. At about 8h30m UT (3:30 a.m. EST, 12:30 a.m. PST), Europa's 1.0"-diameter disk covers 58 percent of the diameter of Ganymede's 1.7"-diameter disk. At midevent you'll see the combined light of the pair drop 23 percent.

The November 20 event occurs shortly after 5h UT (midnight EST and 11 p.m. CST on the 19th) and can be seen from the eastern half of North America shortly after Jupiter rises. Unfortunately, Jupiter is below the horizon for observers in the western part of the continent. The first event, on November 13, happens before Jupiter rises in the Western Hemisphere but will be a nice sight from Europe.

THE GALILEAN SATELLITES begin a series of mutual occultations and eclipses in November that will last for over a year. The best event for Western Hemisphere observers this month occurs on the morning of November 27, when Europa partially occults Ganymede.



TELESCOPIC PLANETS

The two inner planets spend most of November lost in the Sun's glare. Mercury is visible in the evening sky during the second half of the month, but it reaches a peak altitude of just 5° above the southwestern horizon thirty minutes after sunset on November 30. Venus, which is in superior conjunction with the Sun on November 1, won't come back into view until about mid-December, when it will appear very low in the southwestern sky shortly after sunset.

This is the last month for you to get a good view of Saturn in the evening sky. The ringed planet sets about three hours after twilight ends on November 1 and just over an hour after twilight ends on the 30th, so it is not very high in the sky for very long. Still, the 36"-diameter ring system encircling the 16"-diameter planet is a gorgeous sight under even relatively poor conditions and well worth a quick look in the early evening.

Saturn's celestial companions, Uranus and Neptune, are even closer to the horizon than Saturn is when twilight ends. All you can expect to see of Uranus is a 3.5"-diameter, blue-green disk that glows at magnitude 5.8. Neptune is even harder to get a good view of — it's an 8th-magnitude, blue-gray disk just 2.2" in diameter.

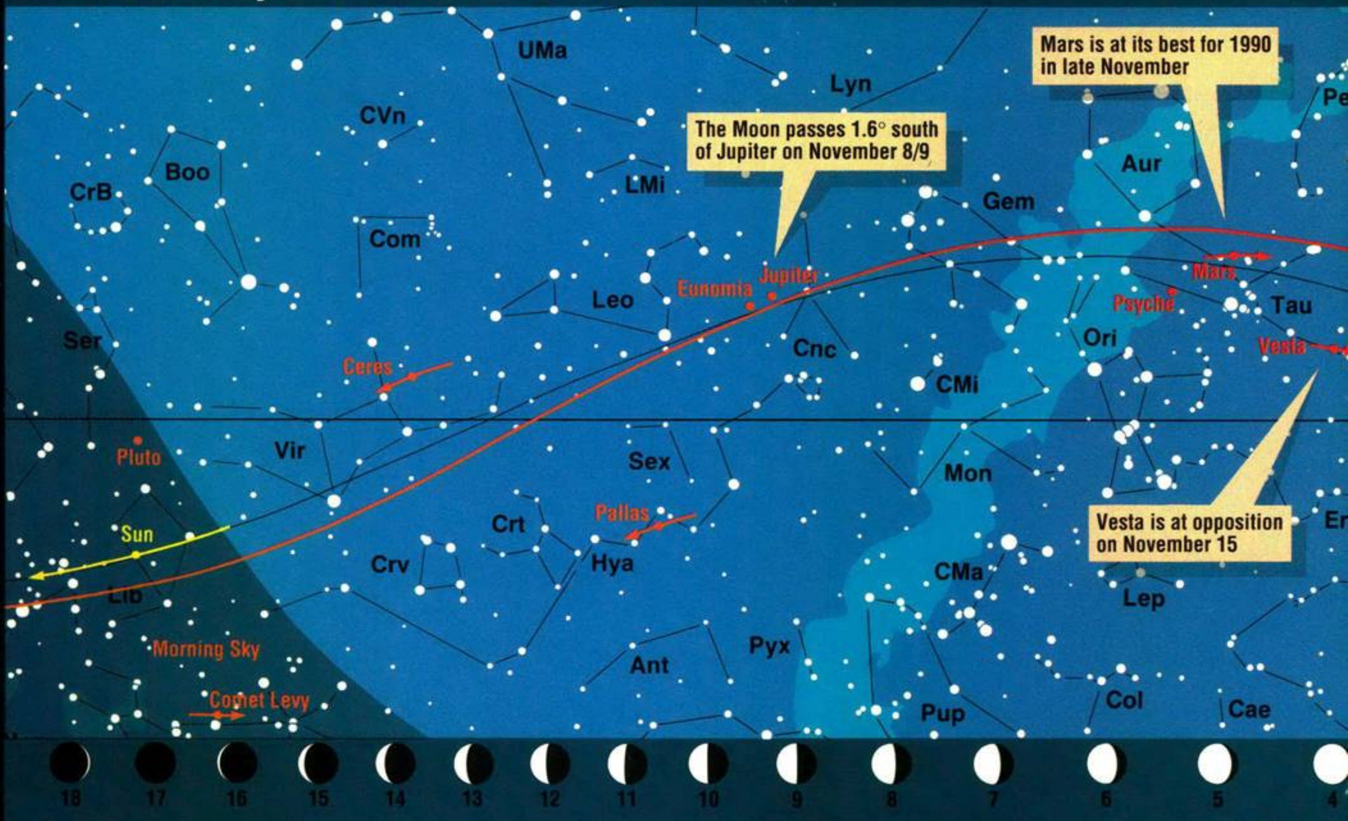
ASTEROIDS IN THE EYEPIECE

Asteroid 4 Vesta, the brightest of all the asteroids, reaches opposition on November 15. With a high albedo of 23 percent and a relatively close distance to Earth of 1.6 AU, Vesta approaches naked-eye visibility at magnitude 6.5.

Vesta moves from Taurus into Cetus during November and crosses into Aries by the end of the year. You can use the map or table of coordinates on the opposite page to locate this chunk of material left over from the formation of the solar system. And because this asteroid is relatively bright, you should have little trouble identifying it. □

Rick Shaffer is a technical group leader at JPL in Pasadena, California. He is leader of the data management team on the Ulysses *project, which is scheduled for launch in October.*

The Solar System November 1990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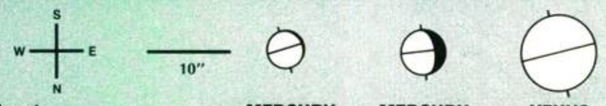
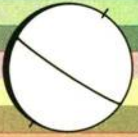
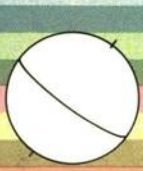
Mars is at its best for 1990 in late November

The Moon passes 1.6° south of Jupiter on November 8/9

Vesta is at opposition on November 15

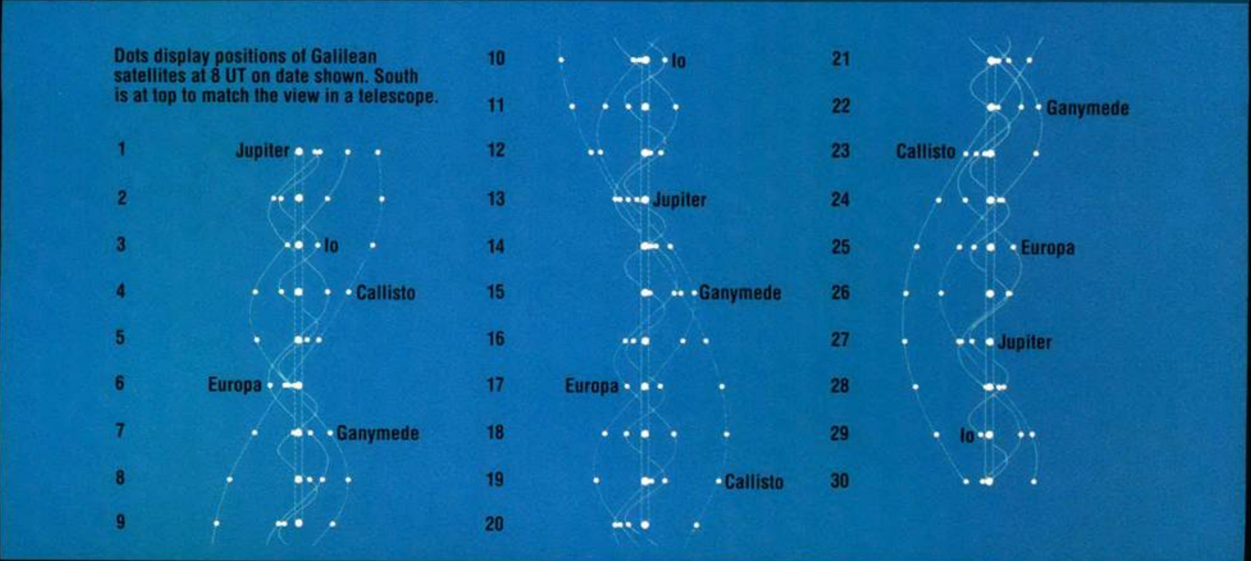




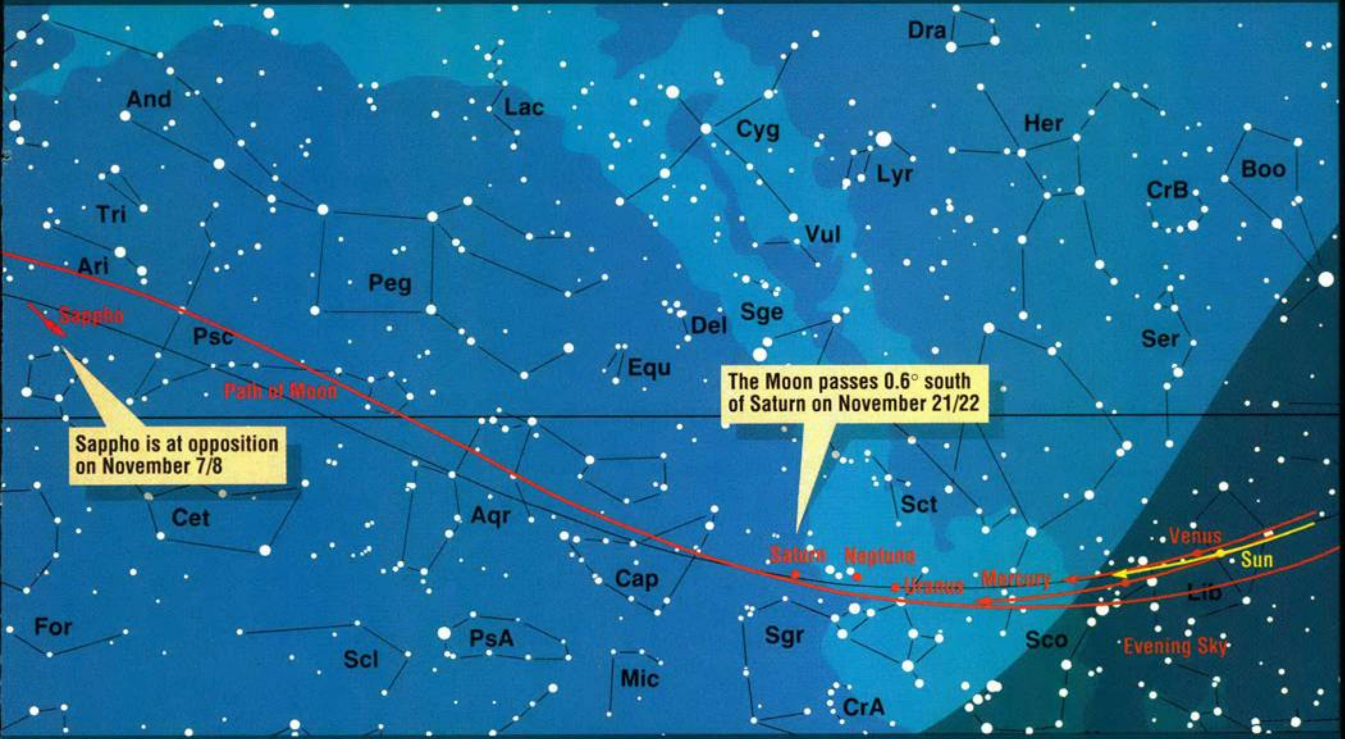


Planet	MERCURY	MERCURY	VENUS	MARS	MARS
Date	November 15	November 30	November 15	November 1	November 30
Magnitude	–0.5	–0.4	–3.9	–1.6	–2.0
Angular Size	5.0"	5.9"	9.8"	17.1"	17.8"
Illumination	93%	77%	100%	96%	100%
Distance (AU) from Earth	1.355	1.145	1.710	0.548	0.526
Distance (AU) from Sun	0.460	0.403	0.725	1.474	1.512
Right Ascension (2000.0)	16h15.8m	17h49.2m	15h34.5m	4h49.5m	4h09.6m
Declination (2000.0)	–23°05'	–25°52'	–18°50'	22°34'	22°36'

Jupiter's Moons



Dots display positions of Galilean satellites at 8 UT on date shown. South is at top to match the view in a telescope.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Uranus
Mercury
Venus
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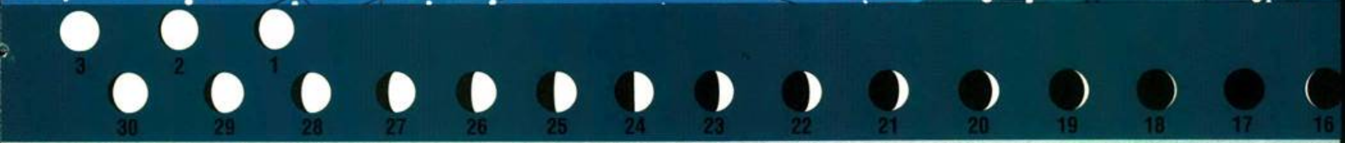
Sappho is at opposition on November 7/8

The Moon passes 0.6° south of Saturn on November 21/22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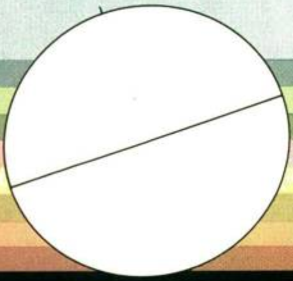
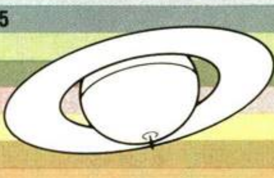
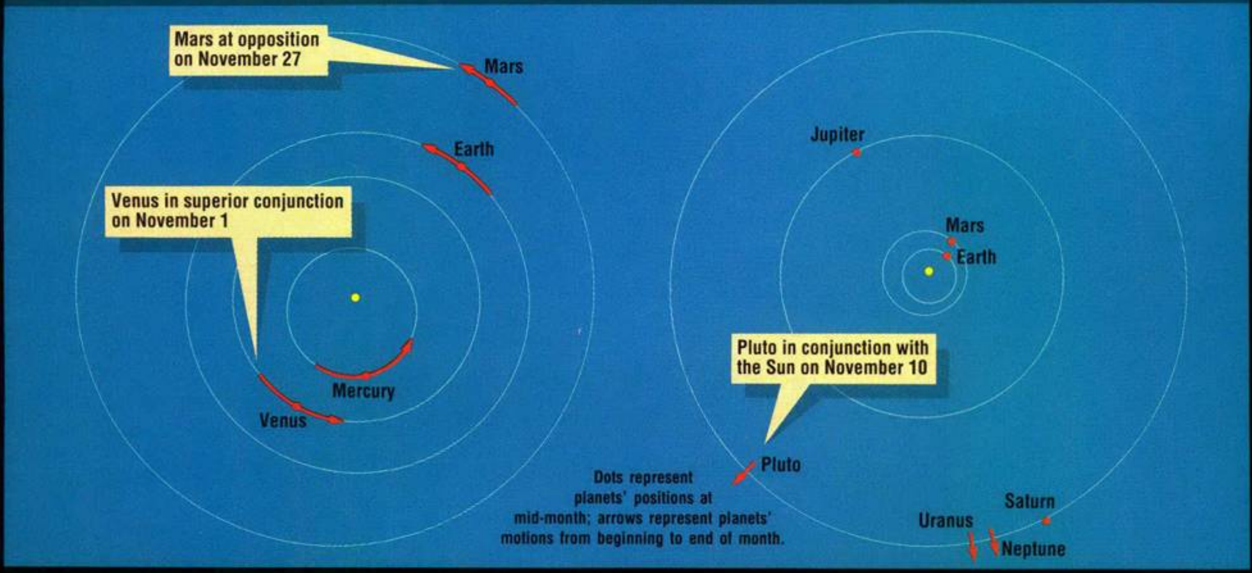



JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
November 15	November 15	November 15	November 15	November 15
−2.2	+0.6	+5.8	+8.0	+13.8
39.2"	15.8"	3.5"	2.2"	0.1"
99%	100%	100%	100%	100%
5.017	10.477	20.127	30.827	30.617
5.265	9.997	19.437	30.203	29.664
9h03.9m	19h31.0m	18h31.7m	18h54.7m	15h18.6m
17°19'	−21°53'	−23°34'	−22°02'	−2°57'

The Planets in Their Orbits


Mars
Earth
Mercury
Venus
Jupiter
Mars
Earth
Pluto
Saturn
Uranus
Neptune

Mars at opposition on November 27

Venus in superior conjunction on November 1

Pluto in conjunction with the Sun on November 10

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

ASTRONOMY Tests the NGC-MAX

It's a black box that helps you find thousands of deep-sky objects. It's not cheap, but it works. And all without polar alignment.

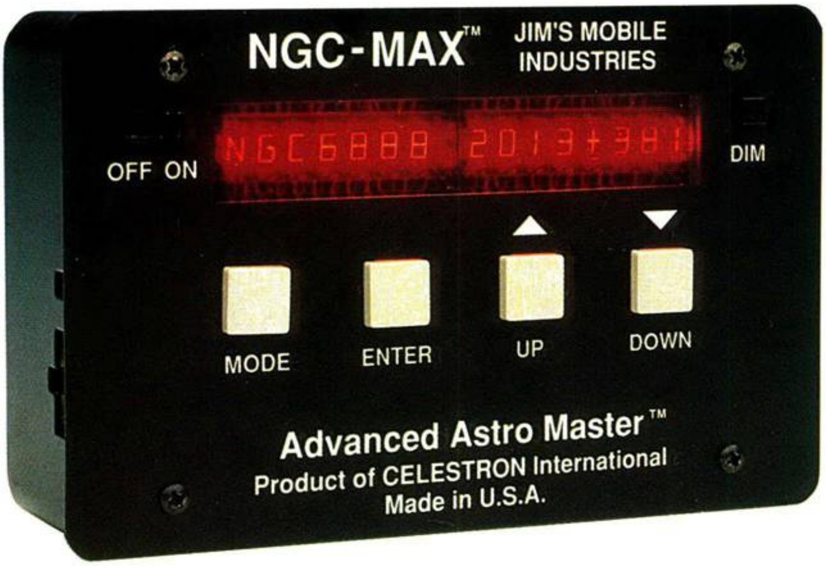
by Alan Dyer

If you're like me you've been suspicious of all the electronic gizmos on the market that promise to do just about everything but look through the eyepiece for you. As an "old guard" observer, I considered the use of any computerized gadget to track down celestial objects as somehow cheating. Or at the very least they were a technological shortcut that prevented you from learning the sky. Digital setting circles (heck, even real setting circles!), CATs, and the like were for wimps, right? *Real* observers didn't use them; real observers didn't *need* to use them!

Well, count me in as a convert. I've used the NGC-MAX and I like it. It works as promised and takes much of the drudgery out of tracking down deep-sky objects, especially the ones that are tough destinations for a star-hop. In fact, on my first night out I forgot I was supposed to be critically reviewing the product and just got carried away effortlessly moving from one object to another. With the NGC-MAX guiding the way, I found I could quickly follow any observing whim.

The Facts about the MAX

The NGC-MAX unit itself is a compact 4.5- by 3-inch black box that can help you find thousands of deep-sky objects. The installation kit comes with two encoders. These little devices attach to the axes of the telescope and send pulses to the computer to tell it how far the scope has moved. You still do the moving, however; this product does not have motors to move the telescope for you. The $829 NGC-MAX is essentially a very smart set of digital setting circles; it can tell you where your telescope is pointed and where your telescope should be pointed. But *you* do the pointing. As such, it is similar to the CAT (Computer Aided Telescope) accessory we reviewed in the December 1987 issue.



THE NGC-MAX can be added to most popular telescopes. It provides "smart" digital setting circles that can guide you to thousands of celestial objects.

The MAX's control box contains the LED readouts and the microprocessor electronics, including the ROM (Read Only Memory) chip that contains all the data about the objects. Burned into the ROM chip are data on the 110 Messier objects, 7,840 NGC objects (with data taken from the *Revised New General Catalogue*), and 363 stars, including many double stars. The latest models also contain information on planetary positions, allowing you to track down Uranus, Neptune, and Pluto or bright planets in the daytime. To find planets you must enter the current date. A special non-volatile memory also allows you to enter coordinates for up to 25 objects of your own. These remain in memory even after the power is turned off. The unit operates on a single 9-volt battery.

The NGC-MAX is sold by JMI, a small company that many readers will know as Jim's Mobile Industries. JMI doesn't make the MAX; it is actually made by Tangent Instruments of Mountain View, California. Tangent sells the same electronics package to Celestron (who markets a product almost identical to the NGC-MAX called the Advanced AstroMaster) and to Lumicon (their unit is the NGC Sky Vector). JMI's product is available for Celestron and Meade telescopes (except for Celestron scopes on the small Polaris mount) as well as for many other brands of telescopes such as Astro-Physics, Coulter, Questar, Takahashi, and TeleVue.

Installing the MAX

The prospect of installing precision encoders sounds like a daunting chore. However, I'm happy to report that the installation of the NGC-MAX was quite easy. All the necessary hex wrenches were supplied. Total installation time was about 30 minutes. I encountered only a couple of minor problems: the bolt through the center of the large RA gear was not as depicted in the instructions and it was also not clear from the diagram which two screws you use to attach the RA encoder to the base of the fork arms. As luck would have it, I used the wrong two, which then caused the encoder gear to slip as it hit the screw heads. After figuring out which were the right screws the rest of the installation went well. The only other quibble I had with the instructions was that some screws were shown that weren't needed or were already attached. For those of us who can't tell a 6/32 screw from a 10/32, a clearer diagram and labelling of kit parts would be nice. This would also ease the worry you have at the end when you find you have a bunch of little screws left over.

For the Schmidt-Cassegrain scope we used, no drilling, filing, tapping, or any other intrusive modifications were needed. Everything fit as it should. However, I thought the plastic covers supplied to fit over the encoders, while making for a cleaner appearance, were flimsy and didn't match the metal construction of the rest of the telescope. They looked like cheap add-on components.

On the vintage Meade 2080 we used, the cover over the RA encoder stuck up enough that the telescope tube would no longer swing down through the forks. The end of the tube hit the cover, making it impossible to fold up the telescope to fit into the carrying case. However, JMI told us that on all other Schmidt-Cassegrain scopes, including newer models of the 2080, this does not happen.

My pet peeve with electronic add-ons is the tangle of cables that go along with such products. In the case of the NGC-MAX a cable runs from each of the two encoders into the computer box. Both cables use phone-jack connectors on the ends to ensure firm connections to the encoders. To help prevent the tangle,

INSTALLING THE ENCODERS

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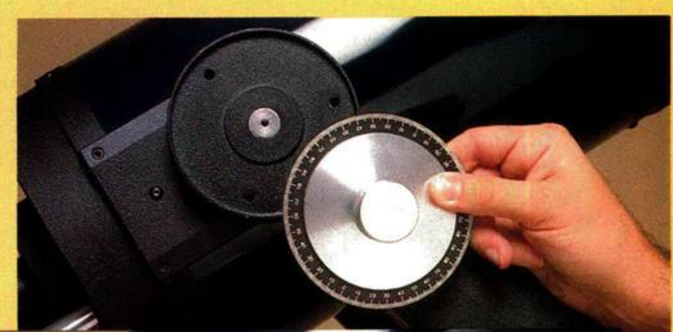

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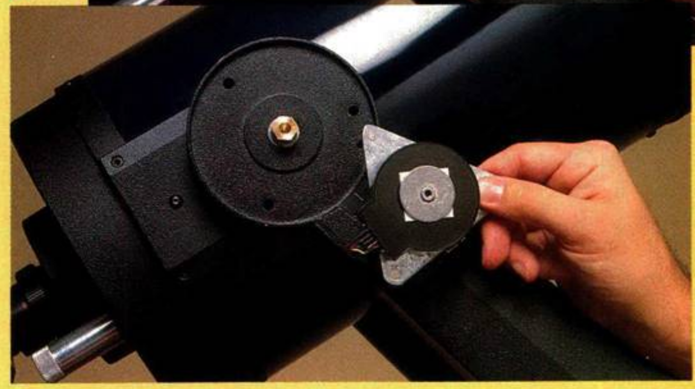
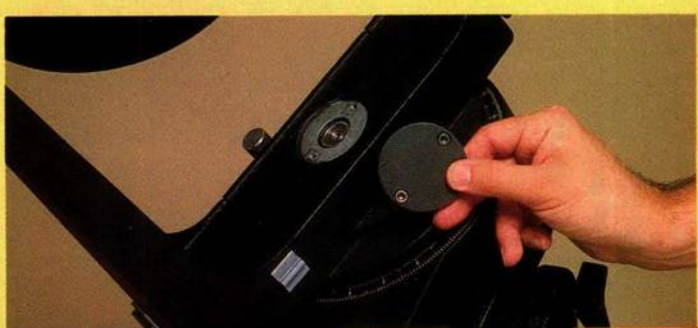


STEP ONE: To install the declination encoder on a Schmidt-Cassegrain telescope, first remove one of the existing setting circles. **STEP TWO:** Attach a coupler bolt (supplied in the kit) to the hole the setting circle came from, and then attach the encoder to the coupler bolt. A plastic cover (not shown) encloses the entire assembly.



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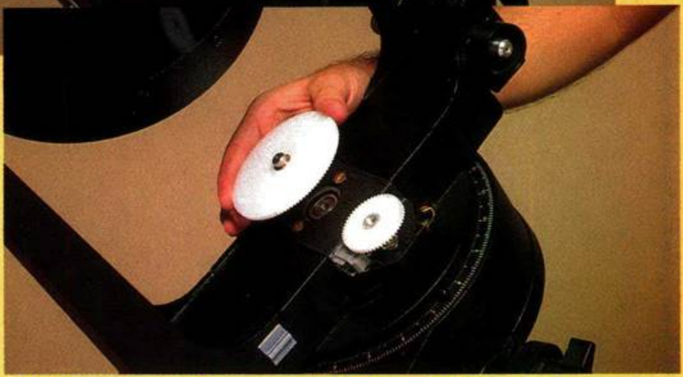

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STEP THREE: To install the RA encoder on a Schmidt-Cassegrain, remove the central cover plate from the polar axis (this plate varies from model to model). **STEP FOUR:** Bolt the encoder assembly to the spot the cover plate came from. Then attach a large gear to the polar axis. A plastic cover (not shown) goes over the entire gear assembly.

adhesive cable clips are supplied to keep the wires tucked along the fork arms and base. As a result, in actual use, the wires weren't bothersome. A couple of times in moving the scope from target to target, I forgot about the wires and rotated the scope 360° in RA, promptly wrapping the cables around the mount. It's a minor problem you have to watch.

I also put the cables in a freezer for a day to see how they would fare in cold weather. They did stiffen up a little but remained pliable enough that they shouldn't cause a problem in winter. Batteries, however, would be a different story. In warm weather, I found the 9-volt battery lasted for five observing sessions of two hours each. This was with the display on full brightness, a worst case. With the display switched to the dimmest setting (suitable for a dark site), battery life would be extended. But in cold weather, battery life would be shortened considerably.

Observing, Robo-Style

The best thing about the NGC-MAX is its ease of calibration. The first models of digital setting circles required you to spend half an hour each night inputting sidereal time, latitude and longitude, and then precisely polar aligning. So much for convenience! But the NGC-MAX and the other similar products on the market, as well as plain digital circles like the DSC-MAX, require only a simple sighting of two stars to get you going. You don't even need to polar align.

Here's how it works. You set up the telescope, preferably with the polar axis pointed north. After turning on the NGC-MAX, you set the declination axis to 0, in other words pointed at the celestial equator. You use your regular setting circles for this. You do this and hit ENTER. It then asks you to align on a star. You can scroll the display through a selection of thirty 1st- and 2nd-magnitude stars. After selecting a suitable star, you center it in the field and again hit ENTER. The MAX responds with a "warp factor" — essentially a measure of how far off the star is from where the MAX thinks it should be.

After aligning on the first star you swing the telescope to a second alignment star at least 45° away from the first and punch it in. That's all there is to it. I found that as long as I was searching for objects in the area of the sky around and between those two stars, the MAX always brought me to within 1/2° of the target. Swinging to other areas of the sky introduced greater errors, up to 2° or 3°. The answer here was to recalibrate on another star in that section of the sky (there was always one available from the list). This dramatically increased the accuracy for that area.

NGC-MAX
JIM'S MOBILE INDUSTRIES
OFF ON
DIM
MODE
ENTER
UP
DOWN
Advanced Astro Master
Product of CELESTRON International
Made in U.S.A.

THE RA AND DEC MODE indicates the current position of the telescope.

NGC-MAX
JIM'S MOBILE INDUSTRIES
OFF ON
DIM
MODE
ENTER
UP
DOWN
Advanced Astro Master
Product of CELESTRON International
Made in U.S.A.

THE CATALOG MODE allows you to select one of the planets, Messier, NGC, or bright stars in the programmed catalogs.

NGC-MAX
JIM'S MOBILE INDUSTRIES
OFF ON
DIM
MODE
ENTER
UP
DOWN
Advanced Astro Master
Product of CELESTRON International
Made in U.S.A.

THE GUIDE MODE tells you how far you have to move the scope to center the object. In this case we need to move the scope 9.5° east and 18° south to find M57.

THE CONTROL PANEL is deceptively simple but actually allows easy access to several different functions and can display a wide range of information.

To test just how smart the NGC-MAX was, on one night I purposely pointed the polar axis toward the Big Dipper in the northwest. I then did the two-star alignment on Arcturus and Altair. The MAX still brought me to within 1/2° of the Ring Nebula (overhead) and M4 in Scorpius (due south). M13 (also nearly overhead) was dead center, but M81 and M82 in Ursa Major to the north were substantially off by 3° in RA and 1° in declination. Recalibrating on a new star in the north fixed this. In fact, the NGC-MAX will work even on alt-azimuth-mounted telescopes like Dobsonians. (But beware: You may be shunned at star parties by the observers who despise setting circles!)

While polar alignment is not required, getting the telescope reasonably close to the Pole does help the MAX's accuracy around the sky. The critical calibration, however, is the initial zero setting of the declination axis. On one evening I purposely set the dec. axis to +20° for the initial calibration. After aligning on Arcturus and Vega, the Ring Nebula still ended up only 0.8° out in RA and 0.5° out in declination, showing that even the "dec. = 0" setting is somewhat forgiving. But with the dec. axis set to –40° at the start, the scope ended up 13° away from the Ring — not surprisingly, the MAX had been fooled.

The Many Modes of MAX

Finding objects is the NGC-MAX's forte. You can use it in the straight "RA and Dec." mode where it will tell you the telescope's position as you move it around the sky. This is the extent of the capabilities of "dumb" digital setting circles. To find an object with them you must look up the coordinates in a reference book and move the scope so the digital readouts match the position. With the NGC-MAX, however, you can go one step further. You can switch to the "Catalog" mode and select one of the 8,000 objects programmed in its memory. When you then switch to the "Guide" mode, the display changes to an indication of how far away in degrees you are in RA and declination. You move the scope until the displays read 0 in both directions. When you get within 10° of the target the displays switch to an accuracy of 1/10th of a degree, making it easy to do the final aiming.

One idiosyncrasy I found was that the magnitudes for objects in the Messier list were quite different than the magnitudes for the same objects in the NGC list. It looks like the Messier data came from the *Sky Catalogue 2000.0* and the NGC data from the *RNGC*. A quick sampling through the MAX's lists turned up a few errors, such as NGC 281's being listed as an open cluster (it's a nebula) and NGC 1049's being listed as "unverified" (it's a globular cluster). Some bright planetary nebulae, such as NGC 1535, did not have any magnitudes listed, despite the fact the magnitudes are well known. These minor errors and omissions are present in the original *Revised New General Catalog,* and the NGC-MAX simply repeats them. In future editions of the MAX and other similar products, it would be nice to see them use the computerized *NGC 2000.0* database — it's more complete than the *RNGC.*

Another neat feature is the "Identify" mode. Aim the telescope at a mystery object and it will tell you what it is. On command, the LED display can scroll from right to left with a message telling you the current object's name, magnitude, type, constellation (for some objects), and *Sky Atlas 2000* chart number.

You can also use the NGC-MAX to help polar align. After aligning on a star, it will then guide you over to Polaris. You then adjust the altitude and azimuth of the mount to get Polaris in view. This procedure compensates for the offset of Polaris from the true celestial pole and actually aims the scope at the pole. However, when I followed this process I found that although the MAX brought the scope close to the pole it was not close enough for critical applications. Checking the drift of a guidestar at high power, I found that after 10 minutes, the star had drifted off about 30 arcseconds in declination. Astrophotographers may still need to use their time-tested star-drift methods for accurate polar alignment.

However, astrophotographers will appreciate the built-in timer. It counts up in seconds from zero, and keeps counting in the background even if you switch the MAX over to other modes.

Deep-sky observers will also appreciate the user-definable objects. You can enter the coordinates (but not the names or catalog numbers) of up to 25 objects. In this way you can use the NGC-MAX to find deep-sky targets not in the *RNGC* or Messier catalog. For example, one night I entered that night's coordinates for Comet Levy, and the MAX located it precisely. Since the NGC-MAX control box can detach easily from the encoders and telescope, you can use it during the day at your desk to conveniently enter a selection of objects for that night's viewing.

Finally, you may well wonder how all these functions are possible with only four buttons. The MODE button allows you to select various functions. The ENTER button executes a command. The UP and DOWN buttons scroll from one mode to another and from one object to another or increment the numerals from 0 to 9 when choosing an NGC or Messier object or a star from one of the catalogs. Since each button performs various functions depending on which mode you're in, the operation does take a little getting used to. But after a couple of nights, I found myself quite at home with the controls. The reason for the simple controls is for ease of operation in the dark with gloves on, a design you soon come to appreciate. While units like the CAT look much more impressive, their complex array of buttons are more difficult to operate.

NGC-MAX

NGC-MAX
MODE
ENTER
UP
DOWN
Advanced Astro Master

A digital setting circle system with a programmed memory of 8,000 objects, including the planets.

Manufacturer: JMI Inc.,
1960 County Road 23,
Evergreen, CO 80439;
(800) 247-0304 (orders);
(303) 277-0304
(information).

List Price: $829.00.

Owners of older model NGC-MAX units can upgrade to the latest ROM chip (planet positions, improved accuracy, *Sky Atlas 2000* chart references) for $25 (free if you purchased the NGC-MAX after May 1990).

Warranty: One year limited.

Pros: Easy to install and calibrate; accurate; convenient to use.

Cons: Expensive; encoder covers flimsy; cables can tangle; short battery life; repeats errors of RNGC database.

Summary: A well-engineered product that allows the user to find and identify deep-sky objects. A luxury accessory that most observers could benefit from but would be put to best use by knowledgeable observers.

However, the NGC-MAX, unlike the CAT, does not allow you to sort out deep-sky objects by search criteria. For example, you can't instruct the MAX to show you just Messier globular clusters brighter than 10th magnitude (or some other sorting). To devise a program of objects for a night's viewing, you still have to do a little homework selecting objects.

Do You Need One?

At $829 the NGC-MAX is an expensive accessory. You certainly expect it to work well; in our case it did. Should you buy one? If you don't know the constellations or the identities of bright stars and don't have any idea of what objects are worth looking at, then even with the power of digital setting circles at your command you'll still be lost in the stars. And out $829.

I feel that an accessory like the NGC-MAX is most useful for people with a solid understanding of the layout of the sky and some experience with deep-sky observing. If you've had a telescope for several years and are finding that you're not using it much anymore, a unit like the NGC-MAX could be just the thing to rekindle your interest in observing. Perhaps tracking down the sky's "top ten" deep-sky targets is as far as you ever got; the NGC-MAX will take you much further into the deep-sky realm.

Plus, there is a way to save money. You can now get most of the NGC-MAX's capabilities but with a more limited selection of objects in a new unit called the NGC MiniMAX. For about $200 less, it has 1,000 objects in its database, enough to include most deep-sky objects brighter than 12th magnitude. (Lumicon's Sky Vector II is a similar product.)

Either in the Max or Mini forms, these smart digital setting circles can open up vast new stretches of the sky for a lot of observers. They're an expensive luxury, but using them can be a great deal of fun. □

Mars Shows Its Stuff

Knowledgeable observers are anticipating a first-class Martian opposition this autumn. The Red Planet will be slightly smaller than at its last opposition in 1988, but much higher in the sky and easier to view.

by Russ Sampson

If you've never viewed Mars through a telescope, now's your chance. This autumn the planet is at opposition to the Sun, opposite the Sun in the sky. Consequently, it is big, bright, and well-placed for observing in the northern sky. Even if you're an old hand at Mars-watching, you'll want to get outside and take advantage of what will be the best opportunity to view the Red Planet for many years to come.

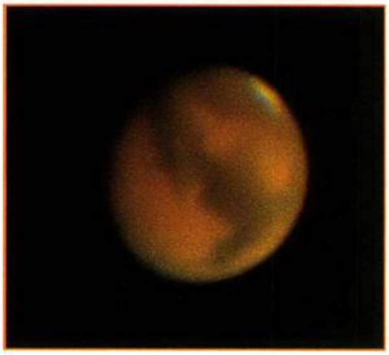
The Martian surface is covered with interesting details that are visible in small telescopes — white polar caps, dusky surface markings, clouds of dust roaming the Martian surface. When you think about it, being able to see these features is an amazing feat: the planet is some 78 million miles away and measures a mere 4,200 miles across, just over half Earth's diameter. And yet a small telescope with a good quality mirror or lens can pick out features on the Martian surface as small as several dozens of miles across.

However, to see Mars at its best you'll also need to observe the planet on nights when the atmospheric seeing is steady, allowing an undistorted image of the planet. Don't be afraid to use high power, but only on nights when the seeing is steady. Also, you'll need to familiarize yourself with the planet and its features.

Finding Your Way around Mars

The map and table on page 71 are designed to show what features on Mars will be visible during the six-week period from early November to mid-December, when the planet will be at its best. The map will let you determine exactly what is visible at a given time on a given night. Below the map is a quick reference table to help locate the central meridian of Mars. The central meridian is a line stretching from pole to pole, cutting the Martian disk in half as seen in your telescope. Once you have determined what central meridian is currently visible on the planet at a given time, a quick look at the map shows what features you can expect to see on the disk.

The table is calibrated for midnight local time. To use it, find your time zone on the left side of the table and then the date you will be observing. Trace a line from this point straight up onto the map. This line is the position of the central meridian of Mars at midnight local time on that date. If you plan to observe before or after midnight, move your meridian left or right according to the scale at the bottom of the chart. For example, if you are living in California (Pacific Standard Time or PST) and plan to observe Mars on November 17th at midnight, you would see Meridiani Sinus (0° Martian longitude) almost dead center in the disk of the planet. If you were to wait four hours, you'd see Mare Erythraeum and Aurorae Sinus (40° to 50° Martian longitude) at the center of the disk.



THE RED PLANET will be perfectly poised for observation this November and December. Photo by Donald C. Parker.

At the eyepiece, features about 60° on either side of the central meridian will appear about the same shape as on the map. But features lying farther from the central meridian will appear foreshortened in comparison to their outline on the map. So the west coast observer out at midnight on November 17 would recognize the distinct shape of Sabaeus Sinus extending out toward Mare Serpentis on the east side, while on the west side of the disk, he or she would see Margaritifer and Aurorae Sinus. Syrtis Major, however, would be a dark, narrow figure just disappearing over the eastern limb.

If you plan to observe a little before or after the dates on the chart, simply move the markers 44° for every additional five days. If you live in a different time zone, trace the date markers onto the edge of a piece of paper. Move these marks 15° of Martian longitude left or right for each additional time zone. For example, if you are observing from Hawaii, move the date markers 30° to the right of Pacific Standard Time.

What You'll See on Mars

Observers with 3-inch to 6-inch telescopes and average atmospheric conditions should expect to see the planet's most prominent features. The many dark, dusky markings are sometimes called seas. This dates back to a time when Mars was thought to be Moon-like in its geology. The lighter areas were subsequently called deserts or continents. Today the reason for the difference between the light and dark regions is still a bit of a puzzle. What is known is that they are not tied to geologic features but are simply areas with higher or lower albedos.

To simplify things I have divided the planet into three regions. From any time zone these regions should be visible over the span of a few weeks, depending on the time of the night you plan to observe.

BOND

Region 1: 60° to 180°; Early November or Early December

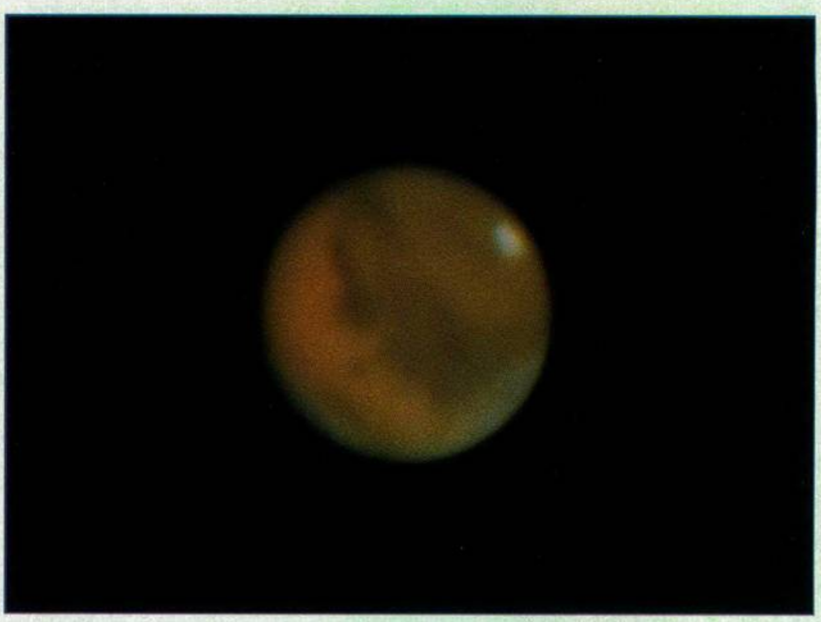
Here the view at the eyepiece is dominated by Solis Lacus and Mare Sirenum, both placed in the southern hemisphere of the planet. Because it appears like a giant circular blob on one side of the planet, Solis Lacus is informally known as the "Eye of Mars." If the atmosphere is steady, you may spot a thin dark line just north of Solis Lacus. This is Tithonius, one of the few dark markings associated with an actual surface feature, Valles Marineris. The largest canyon in the solar system, Valles Marineris was discovered in 1972 by the *Mariner 9* spacecraft. If placed on Earth, it would stretch from San Francisco to Washington, D.C. At its deepest, Valles Marineris is more than three times deeper than the Grand Canyon.

In the late nineteenth century, the astronomer Percival Lowell claimed Tithonius was one of dozens of "canals" which he proposed were created by a Martian civilization. The purpose of this grand system was to transport a dwindling supply of water to their cities and farms. The *Mariner* and *Viking* missions showed these canals as optical illusions, dispelling any notion of a society of Martian engineers. Current thinking indicates that Valles Marineris was formed by tectonic land movements and huge, natural torrents of water many millions of years ago.

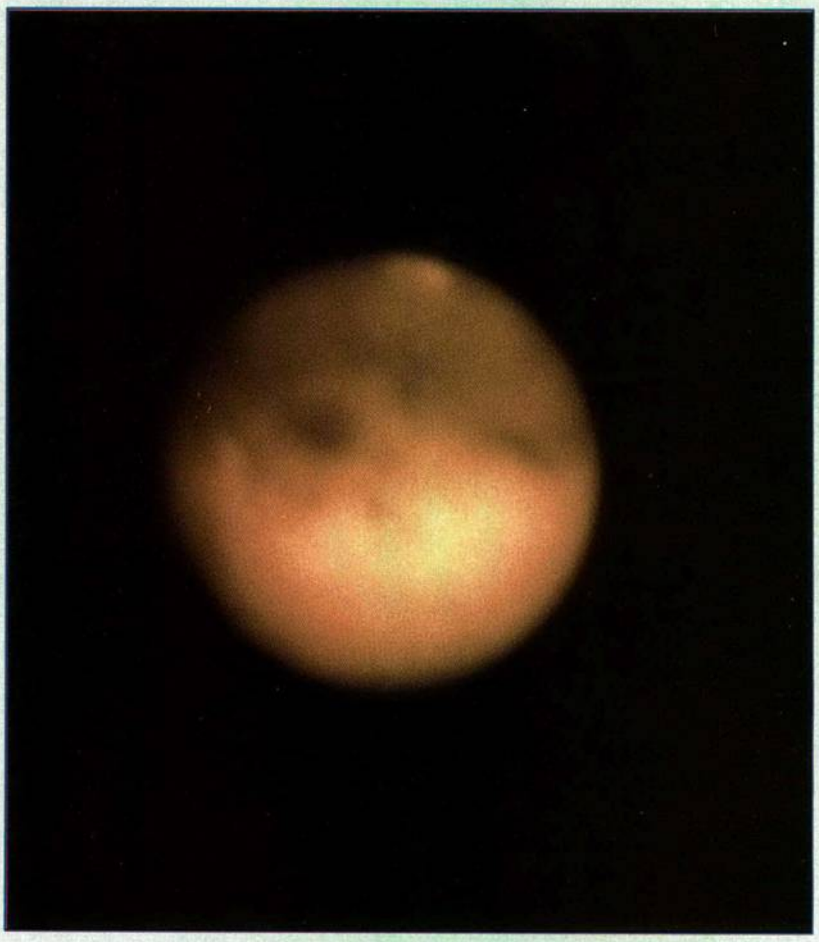
West of Solis Lacus is the broad region around Mare Sirenum. On December 2, 1971, the Soviet Union landed its *Mars 3* probe between the two light-colored continents of Phaethontis and Electris, just southwest of Mare Sirenum. The triumph was short lived, as the lander transmitted only 20 seconds of meaningless data before falling silent.

The northern half of this area is virtually featureless in amateur telescopes. Yet the space probes of the 1970s revealed this area to be one of the most spectacular in the entire solar system. Planetary astronomers call the region the Tharsis Bulge. This area was once volcanically active and is elevated more than five miles above the surrounding plains. It is centered around 105° longitude and 0° latitude, just northwest of Solis Lacus.

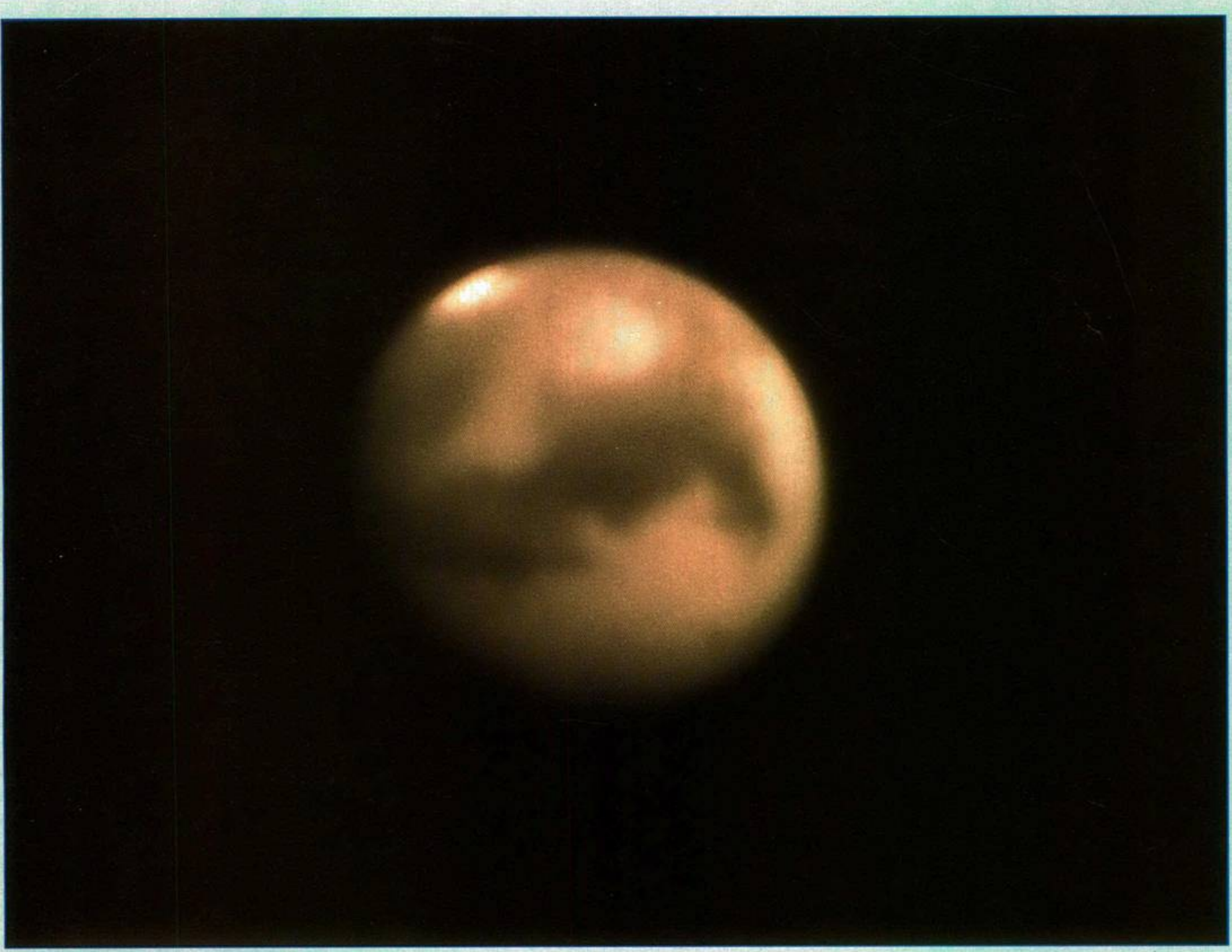
Skirting the area is a collection of volcanos that dwarf the likes of Mauna Loa, Vesuvius, and Fujiyama. The largest is Olympus Mons, which is occasionally visible in backyard telescopes as a tiny circular dot under absolutely exceptional conditions. The summit of this giant



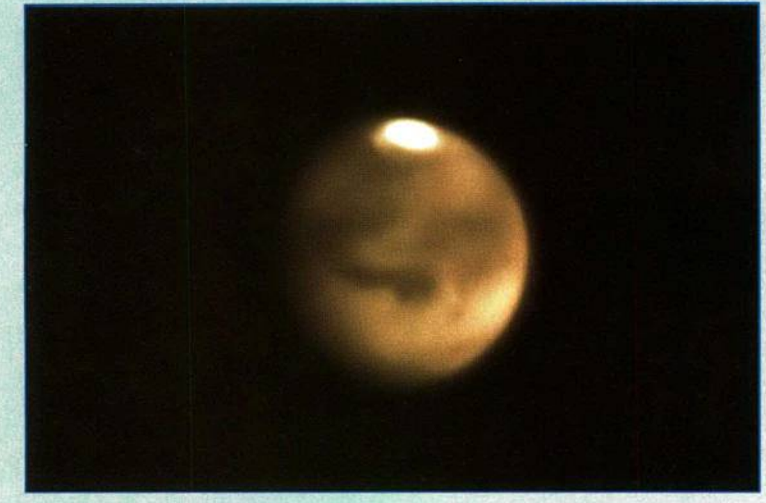
MORNING HAZE hangs over Solis Lacus in this photograph taken on September 21, 1988. Photo by Donald C. Parker.



THE "EYE OF MARS" stares into space like the cold signal from a gigantic civilization. Solis Lacus, however, is a huge circular area that simply does not reflect as much light as the terrain surrounding it. Photo by Donald C. Parker.



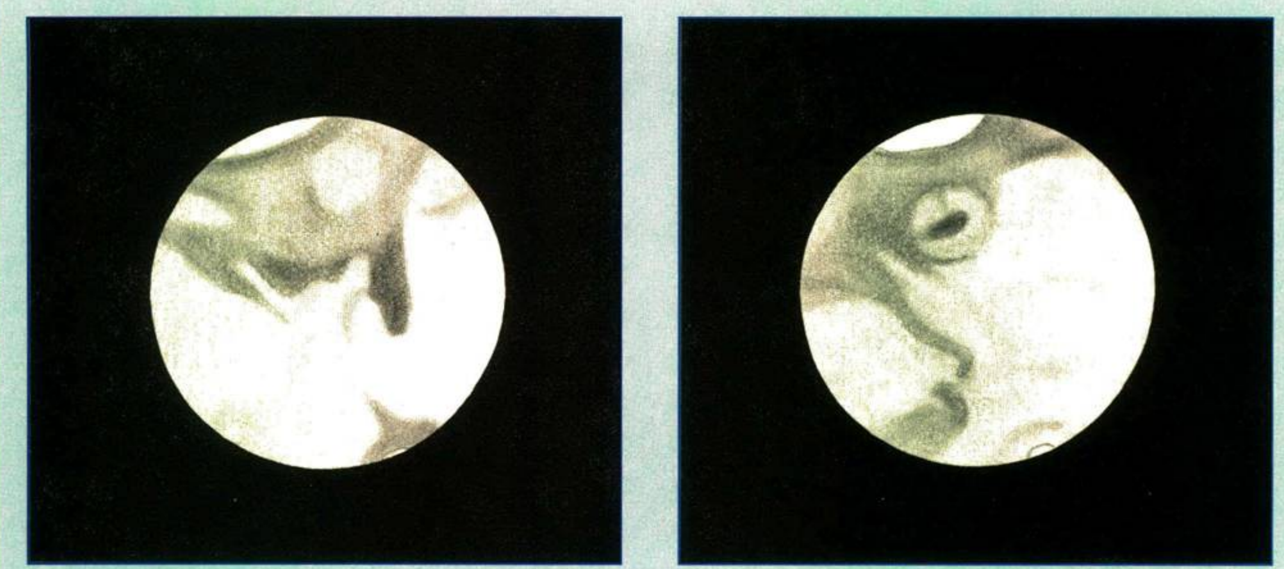
THE MOUNTAINS OF MITCHELL show up on Mars when the South Polar Cap shrinks and leaves a small trailing extension. Also visible in this photo is the bright Hellas basin, just below the polar cap. Photo by Donald C. Parker.



FIVE BRIGHTNESS LEVELS are visible in this photo of the Red Planet: the polar cap, bright limb haze, relatively bright surface areas, dusky gray surface areas, and dark mare. Observing Mars builds a wide range of brightness perception. Photo by Donald C. Parker.

GLOBAL DUST STORMS occasionally sweep the Martian surface and stop the observing fun during oppositions. This photo shows the resulting obscuration from a large storm on November 30, 1988. Photo by Donald C. Parker.

Sketching the Red Planet



The sight of Mars at opposition can be fascinating and beautiful. To remember an image of Mars or to describe it in words is difficult at best. Because of this, many observers of Mars have turned to sketching as a fast, simple, and cheap way to record some of the fine detail they see in the telescope. This year's opposition of Mars offers a good opportunity to try your hand at planetary sketching.

Before going to the telescope, try sketching one of the photographs of Mars in this article. If you place the photo at a distance of several feet, the image will appear as it would in a telescope around the time of opposition.

To start, draw a circle onto a small sketch pad. The Association of Lunar and Planetary Observers recommends that the circle be 42 millimeters in diameter. Carefully sketch the outlines of the features you see. Use a system of numbers to mark the different shades of the features. I use a five point system (with five representing the darkest shade visible) and then paint by numbers. I add the darkest features first, then fill in the subtler features until I have a finished sketch.

Once you have finished this preliminary sketch, copy it by hand onto another piece of paper. Finish the drawing by shading in the markings. Using the proper tools for this exercise is essential — I use soft graphite and the tip on an artist's blending stump to make the subtle shading. You may find, however, that your finger is easier to control than a stump.

A white eraser can be used to make the polar caps. When you make sketches at the telescope, be sure to include the date, time, and conditions on your drawings.

If this opposition sparks your interest in Mars and planetary observing, contact the Mars Section of the Association of Lunar and Planetary Observers c/o Jeffrey Beish, 9460 Toni Dr., Miami, FL 33157.

towers 15 miles above the surrounding plain — nearly three times the height of Mount Everest.

Region 2: 300° to 60°; Mid-November

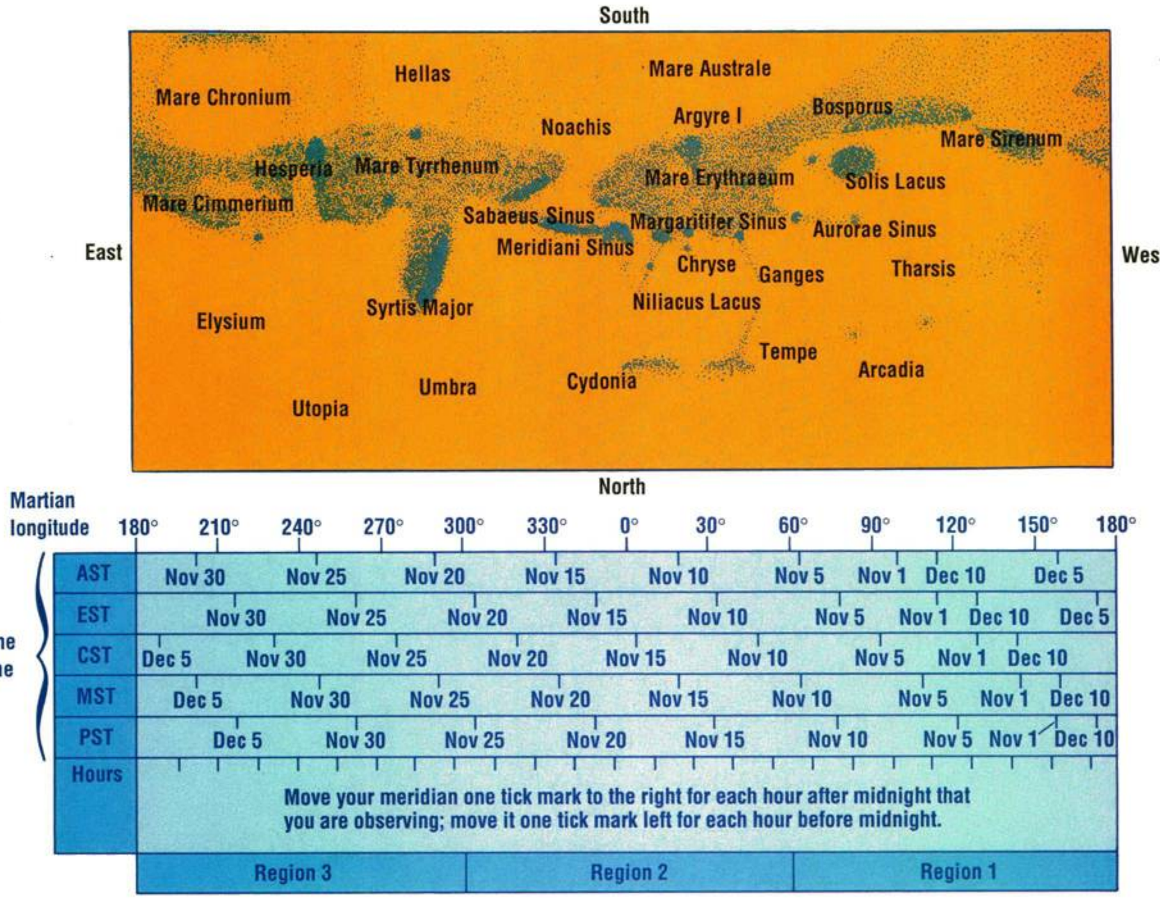
This is the most detailed region on the Martian globe. When the atmosphere is steady, this part of Mars seems to come alive with markings and tones. The most easily recognized and most often depicted dark marking is Meridiani Sinus. This feature was chosen to define the Martian prime meridian (0° longitude), just as Greenwich, England, was on Earth. During moments of good seeing, when the boiling motion of our atmosphere is minimal, the northern side of Meridiani Sinus appears to divide into two distinct prongs.

Extending along the eastern side of Meridiani Sinus is the thin dark curve of Sabaeus Sinus. Together, these two markings resemble a distorted pipe. To the southwest is the great expanse of Mare Erythraeum. The northern end of this feature contains a great amount of detail. Just west of Meridiani Sinus is the triangle-shaped feature Margaritifer Sinus, the starting point for Oxus, one of the most commonly observed Martian "canals." Oxus extends north east from the tip of Margaritifer Sinus and includes the so-called oasis Oxia Palus.

Toward the northern end of the disk you may see Niliacus Lacus, one of the few dark markings in the mid-northern latitudes. Just a few degrees west of the southern tip of Niliacus Lacus lie the now silent remains of the *Viking 1* lander. This robotic spacecraft first touched down on the surface of Xanthe, a section of Chryse Planitia, on June 19, 1976. *Viking* searched but found no signs of life.

Region 3: 180° to 300°; Late November to Early December

This region is a study in contrast. Syrtis Major is one of the darkest and easiest to see of all Martian features. One of the earliest Mars drawings, made by Huygens in 1659, shows what is probably Syrtis Major. Many observers describe its appearance as being like a misshapen Africa. Directly south of Syrtis Major is Hellas, one of the brightest of the Martian features. At 1,100 miles in diameter, this huge basin is one of the largest impact craters in the solar system. Its diameter is 300 miles greater than that of Mare Imbrium, the biggest impact structure on the Moon. To make a crater the size of Hellas, the impacting object would


South
Mare Chronium
Hellas
Mare Australe
Noachis
Argyre I
Bosporus
Mare Sirenum
Hesperia
Mare Tyrrhenum
Mare Erythraeum
Solis Lacus
Mare Cimmerium
Sabaeus Sinus
Margaritifer Sinus
Aurorae Sinus
Meridiani Sinus
East
Chryse
Ganges
Tharsis
West
Niliacus Lacus
Elysium
Syrtis Major
Tempe
Arcadia
Umbra
Cydonia
Utopia
North
Martian longitude 180° 210° 240° 270° 300° 330° 0° 30° 60° 90° 120° 150° 180°
Time zone
AST Nov 30 Nov 25 Nov 20 Nov 15 Nov 10 Nov 5 Nov 1 Dec 10 Dec 5
EST Nov 30 Nov 25 Nov 20 Nov 15 Nov 10 Nov 5 Nov 1 Dec 10 Dec 5
CST Dec 5 Nov 30 Nov 25 Nov 20 Nov 15 Nov 10 Nov 5 Nov 1 Dec 10
MST Dec 5 Nov 30 Nov 25 Nov 20 Nov 15 Nov 10 Nov 5 Nov 1 Dec 10
PST Dec 5 Nov 30 Nov 25 Nov 20 Nov 15 Nov 10 Nov 5 Nov 1 Dec 10
Hours
Move your meridian one tick mark to the right for each hour after midnight that you are observing; move it one tick mark left for each hour before midnight.
Region 3
Region 2
Region 1

FINDING WHICH PART OF MARS IS VISIBLE on a given night is easy. Locate your time zone on the left, then look across to find today's date. Directly above on the map are the features that lie in center of the Martian disk at midnight.

have to be about 100 miles across. Between Syrtis Major and Hellas is a complex area of mottled dark markings that continues to the southeast. Two of the more obvious dark features in this area are Mare Tyrrhenum and Mare Cimmerium.

At the northern edge of the Martian disk is a nondescript plain almost devoid of features. This area, with the unlikely name of Utopia, was chosen as the landing site for *Viking 2*. Scientists selected this area because it appeared flat and featureless in *Mariner* images.

Clouds, Dust and Polar Caps

At the planet's north and south poles, carbon dioxide and water vapor have frozen out to form brilliant white polar caps. Ground-based and spacecraft studies have found that the North Polar Cap is made of water ice with a seasonal crust of frozen carbon dioxide. The South Polar Cap is different, almost entirely composed of frozen carbon dioxide.

Like Earth, Mars has a significant tilt to its rotational axis (25.2°). This produces a cycle of seasonal changes in global temperatures. During the warmer parts of the Martian year, the polar caps retreat as the volatile dry ice sublimates directly into carbon dioxide gas. Since it is now late summer in the Martian southern hemisphere, the South Polar Cap will be small.

The atmosphere of Mars has less than one percent of the density of Earth's, yet clouds and haze can still form on Mars. The most common and the easiest to see are the broad morning limb hazes and the North Polar Hood. Both these phenomena appear as bright arcs outlining the morning and northern limbs of the planet.

Occasionally clouds form over and around the towering volcanos along the Tharsis Bulge. These so-called orographic clouds do not usually form during the late Martian summer, but watch for them just in case. Most clouds and hazes are best seen with a violet or blue filter.

The most dramatic atmospheric event, however, is a global dust storm. These start as bright yellowish clouds and can grow to completely cover the planet, obscuring its entire surface. Amateurs observed several dust storms during the last opposition. Many of these started out as small yellow clouds in the Hellas Basin. The largest dust storm began in a region between Solis Lacus and Argyre I.

Many new observers of Mars got started during the great opposition of 1988. Once you know your way around, each opposition will bring an opportunity to search out finer detail or hunt for subtle changes. Unlike those on the Moon, the dark markings on Mars can change over months and years. So now is your chance to begin your acquaintance with this strange and mysterious world. ☐

Russ Sampson is an avid planetary observer who works at the Edmonton Space Sciences Center in Alberta, Canada.

STARFIRE

TELESCOPES FOR ASTROPHOTOGRAPHY

The features that make a telescope great for astrophotography are often the same features that make a telescope great, period.

by Alan Dyer

I know what you're thinking: "Why would I want a telescope for astrophotography? I'm not interesting in astrophotography. It's too difficult!"

Well, you're partially right. Astrophotography can be demanding. The standards set by today's top astrophotographers are very high and may scare off more people than they attract. A few years ago just about everyone wanted to take pictures through their telescopes, but today a common reaction is "I'll never get results as good as that. I'll leave it to all those masochists out there to take the pictures. I'll just enjoy their results."

But there's no need to put yourself into an "all or nothing" bind. Astrophotography doesn't have to be a deadly serious pursuit. Even if you're a dabbler, you can get images that provide you with a lot of personal satisfaction, especially with the help of today's fast films.

Ah, but what about the expense? I've heard people critical of astrophotography say "Sure, all it takes is money. If you spend enough, you'll eventually get good results." It's a myth that's all too common these days. With today's marketplace rich in high-priced telescopes and accessories, it's also a tough myth to dispel. But the truth is that having an incredible array of custom-made equipment doesn't guarantee success. Nor do good results come only from high-end systems costing $5,000 or more. Award-winning photos don't require *expensive* equipment, just the right equipment.

Selecting the Right Mount

If you're in the market for a new telescope, chances are you'd like to try some photography with it. But even if astrophotography is the last thing on your mind, you undoubtedly still want the best-made telescope in your price range. Astrophotography puts high demands on a telescope's mount and optics. So some of the features that make for a good astrophoto scope also make for a good telescope for discriminating buyers looking for a basic visual-only telescope.

There is one big difference between a telescope for visual use and one for photography, however — the mounting. For a visual scope, the optical system tends to drive your choice, with the aperture of the telescope often being the most important difference between the various models on your short list.

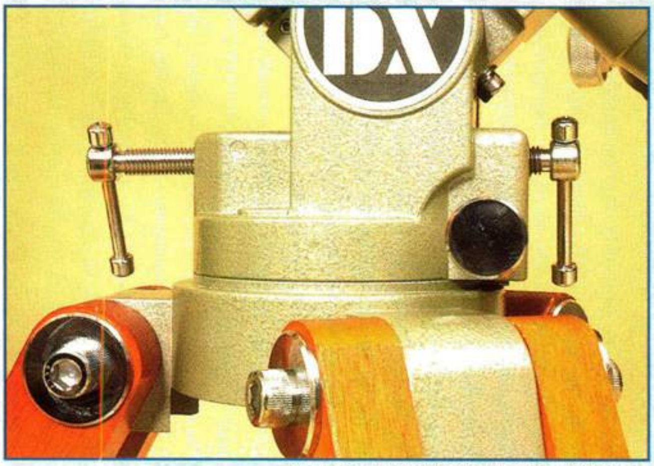
For an astrophoto scope, optics take a back seat to the mounting. If you're deciding between two telescopes, make your choice based on the quality of the mounting. The more solid the mounting, the better — to a point. Remember that unless you're installing the telescope in a permanent observatory, you're going to have to carry the thing around. A mounting should be sturdy but also compact and easy to set up.

The reason the mounting is so important is that every form of photography done with a telescope, from wide-angle piggyback pictures to high-powered planetary portraits, benefits from having the optics held rock steady during the exposure. Even if you're only taking shots of the Moon at 1/250 second, any vibration or wind will blur the picture. On poor mounts, the very act of focusing the scope can shake the image so much that you can never tell if you're really in focus, needlessly introducing another source of error. Even winding the camera to advance to the next frame can jolt a flimsy mount, creating frustration.

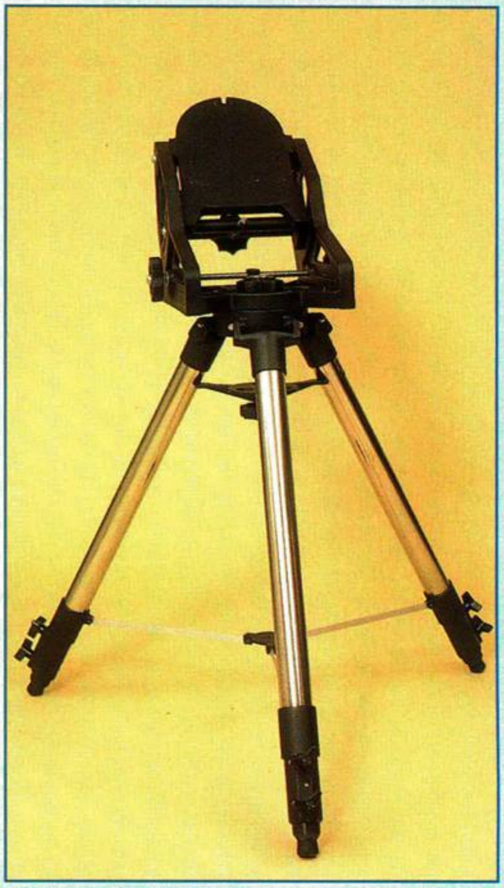
THE SECRET to good astrophotos is a solidly mounted telescope. The Celestron Ultima and the Astrophysics and Takahashi scopes are good examples. Pleiades photo (opposite) by Tony Hallas and Daphne Mount using a 5-inch refractor.

FEATURES TO LOOK FOR

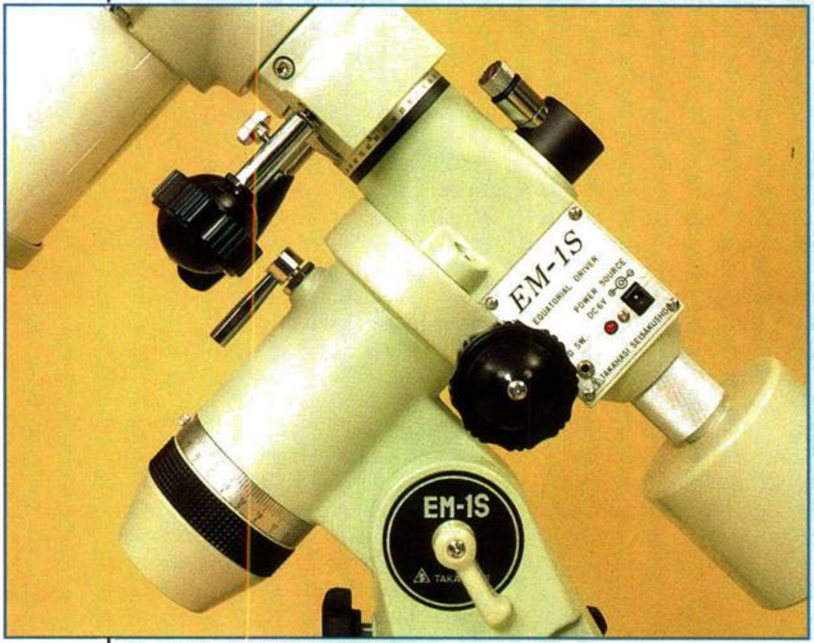
GREAT FEATURES make a great mount. Even if you don't intend to do astrophotography, these features add convenience and stability, which enhance the quality of any telescope.



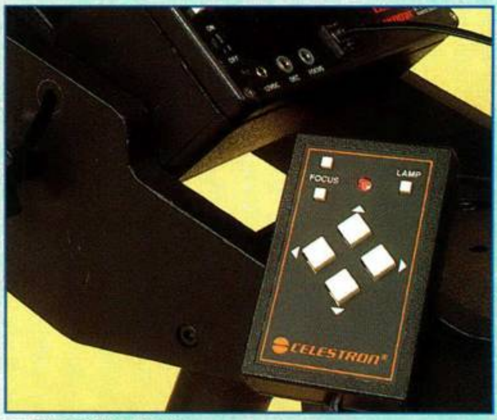
POLAR ALIGNMENT ADJUSTMENTS



A STURDY TRIPOD



A SOLID EQUATORIAL HEAD



SPEED CONTROLS

Ask most astrophotographers and they'll tell you — a solid mount makes picture taking much more pleasurable and the results much better. Here's a checklist of some of the specific features you should look for in a mount:

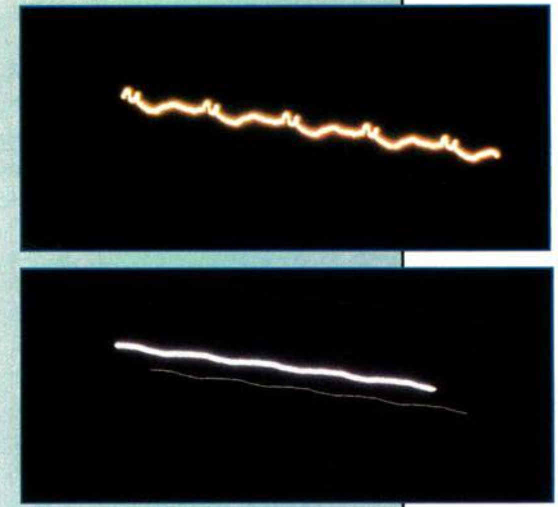
✓ *Equatorial Mount with Clock Drive* — Any exposure longer than a fraction of a second (which means most astrophotos) requires that the telescope track the sky to keep the object centered. This means an equatorial mount with a clock drive is a must. Altazimuth or Dobsonian mounts limit you to snapshot exposures of the Moon and Sun.

✓ *Worm Gear Drive* — The worm-and-wheel type of driving gear is usually better than spur gear drives, though if poorly made, even a worm gear drive will have objectionable driving errors that will blur images during time exposures.

✓ *Large Diameter Wheel Gear* — The larger the main driving gear (the wheel) the more accurate the drive. It will suffer less from short-term speed variations and mechanical flaws (a stated tracking error of ±5 to 10 arcseconds is very good), though again, quality of manufacture is more important than sheer size.

✓ *Mass* — The mounting should be beefy, with large but stubby axes to dampen vibrations.

THE ALL-IMPORTANT DRIVE



A SMOOTH, PRECISE DRIVE (such as at left) is an essential element on a good astrophoto telescope. In the two star trail images, we allowed the star to drift across the field to demonstrate drive errors. In the poor drive (upper), tracking errors caused the image to wander markedly from the central path. In the better drive (lower), the smaller tracking error created a smoother trail largely free of unwanted periodic wanderings.

☑ *Low Center of Gravity* — A heavy mounting shouldn't sit atop a lightweight tripod or pier; nor should the scope itself sit atop an unnecessarily long axis (a common fault of many German equatorial designs).

☑ *Rigid Tripod* — A tripod or pier doesn't have to weigh a ton. It just has to be rigid, with a structure that resists flexing in all directions and has no loose connecting points.

☑ *No Weak Links* — Sometimes otherwise good equatorial mounts are attached to tripods or piers with flimsy connections, with the latitude adjustment point and the tripod often being weak links.

☑ *Polar Alignment Adjustments* — Mechanisms for moving the mounting head or wedge assembly by small amounts from side-to-side in azimuth and up-and-down in altitude are essential for lining up on the pole.

☑ *Polar Alignment Scope* — Some would argue that these devices located in the polar axis of many German equatorial mounts are not essential, but they certainly don't hurt; they can help you get very close to the pole, perhaps close enough for most purposes.

☑ *Smooth Slow-Motion Controls* — These allow you to fine-tune the aim of the telescope, and thus the framing of an object, without shake or backlash.

☑ *Fast/Slow Buttons* — Some means of instantaneously speeding up and slowing down the motor is essential for "guiding" a telescope in right ascension during long exposures.

☑ *Fine Motion on Declination* — The declination slow motion also requires a mechanism capable of fine adjustment (it can be manual or electric).

☑ *Speed Range Control* — Another nice but non-essential feature is a means of adjusting the driving speed of the motor off the basic sidereal rate in order to match the east-to-west speed of the Moon.

☑ *Positive Locks* — When you tighten the right ascension and declination lock knobs, the telescope mount shouldn't wander off target.

☑ *Ergonomics* — It should be possible to easily reach the slow-motion control and RA and declination lock knobs while you're at the camera viewfinder.

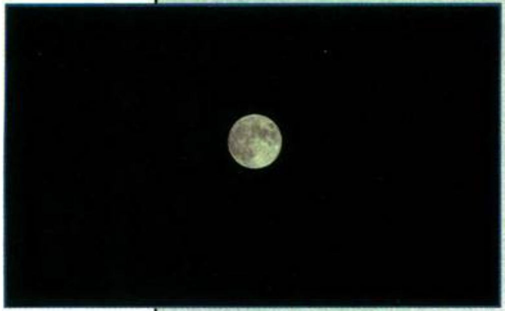
☑ *Portability* — Finally, you have to combine all these features in a mount that breaks down into easily carried components so you can get it out to your favorite site, even if that's only your backyard.

To this list we could also add "versatility." Mounts that allow you to attach a variety of telescope tube assemblies on them (not necessarily all at the same time!) are good choices. If you've chosen the mount correctly you can use the same mount with different optics: long telephotos, wide-field refractors, fast Newtonians, Schmidt cameras, Schmidt-Cassegrains, plus accessory guidescopes — whatever suits the celestial subject.

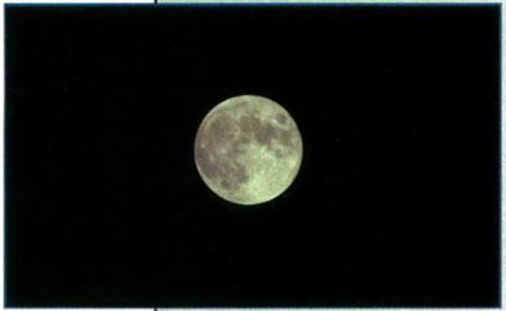
Selecting the Right Optics

While one mount can serve you well, there is no single optical system that could be considered best. It may seem contrary to everything you've been told about telescopes, but a bigger telescope is not necessarily a better telescope, at least not for astrophotography. In fact, there's a lot to be said for keeping the telescope small. That places less demand on the mounting, making a sturdier combination.

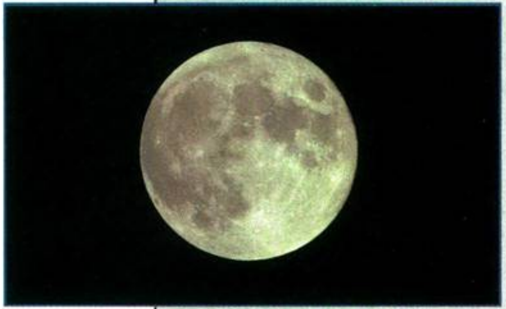
Now, you're saying, "Wait a minute! Don't larger telescopes have



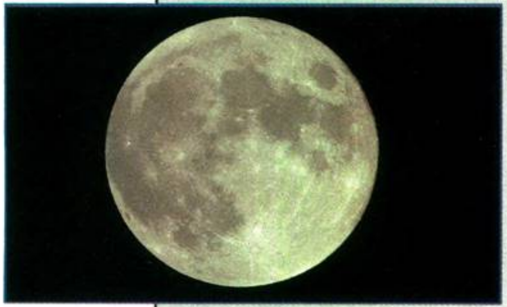
500 mm focal length
= 6° by 4° field



1,000 mm focal length
= 3° by 2° field

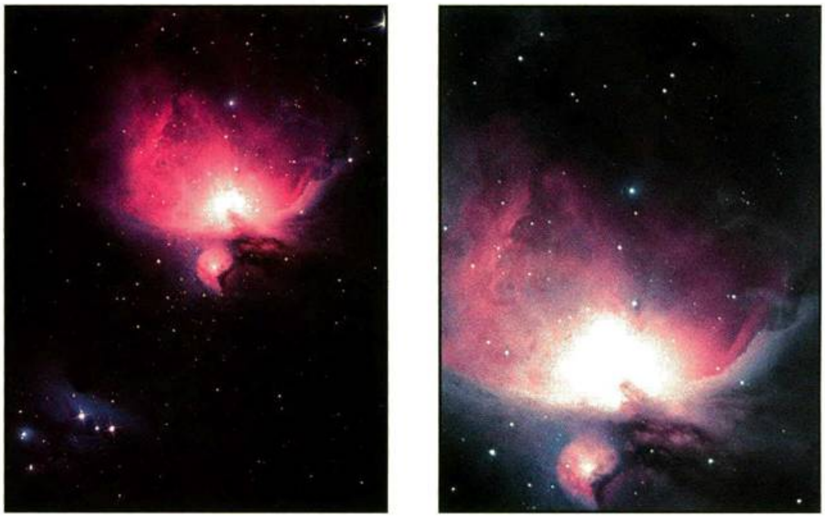


2,000 mm focal length
= 1.5° by 1° field



2,500 mm focal length
= 1.2° by 0.8° field

LONGER FOCAL LENGTHS equal larger image sizes but smaller fields. This series of photos simulates the field of view and size of the Moon on a 35mm film frame with different focal length telescopes.



EXPOSURE TIMES DEPEND ON F/RATIOS not aperture. As an example, both these images are approximately 20-minute exposures. One was taken with a 12-inch f/5 telescope (left) and one with a 20-inch f/5 scope (right). The amount of detail recorded is similar. The larger aperture telescope, however, produced a larger image size in a narrower field of view. Photos by Scott Hicks (left) and Jack Newton (right).

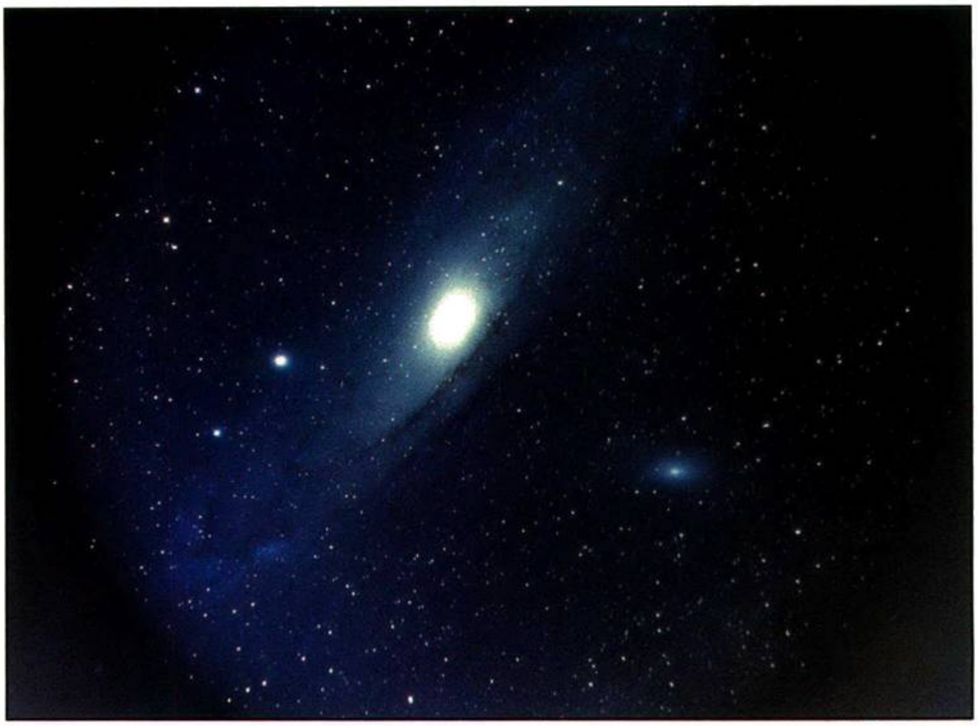
brighter images? Aren't brighter images better for photography?" Right, on the last point, but wrong on the first point. Brighter images do keep exposure times down, something that is very desirable in just about every form of astrophotography. But in photography, brighter images don't come from aperture. They come from "fast" f/ratios. The f/ratio is the focal length of the telescope divided by the diameter of the lens or mirror. Fast telescopes (those in which the focal length is only 4 to 6 times the lens or mirror diameter, that is f/4 to f/6 systems) produce brighter images than slow systems (f/8 to f/16). This is a real advantage for deep-sky photography; fast scopes keep exposures from becoming arduous endurance trials.

So why not go for the fastest scope you can buy? One reason is that faster scopes have shorter focal lengths; they produce images that are brighter, to be sure, but also smaller. For example, let's take two 6-inch telescopes, one an f/4, the other an f/8. Exposures will be only one-quarter as long with the fast scope; a deep-sky object that takes 10 minutes to record at f/4 will take 40 minutes at f/8 — enough to test your patience. But the f/4 system has a focal length of only 600 mm, versus the 1,200 mm focal length of the f/8 system. This means the field of view of the fast system is twice as wide as in the slow scope. For many large deep-sky targets this can be an asset — but every object is also twice as small. Small image sizes mean image detail can get lost amid film grain.

The pursuit of large, detailed images is the main reason deep-sky photographers endure those long exposures with slow systems. It's also the reason deep-sky photographers lust after larger apertures. Big scopes give them the focal length they're after for recording detail in small objects while still providing fast f/ratios to keep exposure times down. For example, to achieve a 1,200 mm focal length in an f/4 system requires an aperture of 300 mm. That's a 12-inch scope, a monster to mount rigidly let alone transport. For most of us, a 4- to 8-inch aperture scope is far more practical and affordable. (Remember, we're speaking of solid equatorially mounted scopes for photography, not light-bucket Dobsonians.)

There are applications for which the "speed" of a telescope isn't important. For shots of the Moon, for example, the subject is bright enough that even an f/16 scope works well. In fact, the extra focal length of a slow scope can be an asset, giving a larger lunar disk. Using a focal length of 2,000 mm the Moon's disk just nicely fills a 35mm film frame.

Planetary photography is the one area in which sheer aperture is helpful. Using only a 3- or 4-inch scope results in slow "effective f/ratios" with the high magnifications needed for good planetary photos. Scopes with less than a 5-inch aperture produce images that are too dim, making for inordinately long exposure times and producing fuzzy images from poor seeing and vibration.



DISTORTED STARS at the field's edge are unavoidable with fast Newtonians. Perfectionists can eliminate this coma aberration by using a coma corrector lens when taking the picture. Photo by Orien Ernest with a 12.5-inch f/5 telescope.

So Which Scope is Best?

We're juggling a lot of variables here: focal length, speed, field of view, aperture — all optimized into a single telescope that has a solid mount you can carry! Wow! Does anyone make such a superscope? No. Every scope is a compromise. But in today's marketplace, you can get very close to an ideal system. Here are some recommendations:

✓ *Fast Apochromatic Refractors*

Advantages — They're fast and compact, have superb optics and a wide field of view, are available with solid, portable mounts, and can be used with medium-format cameras (i.e. Pentax 645 and 6x7) for even wider fields. They are great for deep-sky photography.

Disadvantages — Short focal length produces small image sizes for the Moon, though focal length can be increased with a Barlow lens; small apertures (3 to 4 inches) produce dim images at magnifications required for planetary photography; and they are quite costly.

Outstanding examples — The TeleVue Genesis has great optics on an excellent mount built by Carton Optics of Japan. The Astro-Physics Star12 ED and Starfires are slower but in skilled hands capable of incredible results. The Astro-Physics line of mounts is excellent. The fluorite refractors from Takahashi are unmatched for quality of optics and mounts, though the quality comes at a price.

✓ *Fast Newtonian Reflectors*

Advantages — They're fast, are economical, have a wide field of view, and in 6- to 8-inch sizes the aperture is sufficient for planetary photography. A well-proven instrument used by many astrophotographers over the years.

Disadvantages — Coma at the edge of the field distorts star images in fast systems, though this problem can be corrected with a $300 coma corrector lens (available from Celestron, Lumicon, and TeleVue); the fast optics are often imprecisely made, yielding fuzzy images, especially at high power for planetary work; and the standard mounts and drives are often not of sufficient quality.

Outstanding examples — Celestron Super Polaris C6 (though the mount is a little light for an astrophoto scope of this size); Parks 6-inch and 8-inch Nitelights (on their Petra mount); Parks 8-inch Superior; Takahashi Newtonians and Hyperbolic Astrographs (an unusual and costly design that comes with a corrector lens for wide, flat fields). But most astrophotographers who favor Newtonian scopes use custom-made tube assemblies on special heavy-duty mounts from companies like Byers, Epoch Instruments, Losmandy, or Mathis. If you're really serious about astrophotography, check the excellent large Newtonians (10-inch and up) available from Parks and Meade. However, these models strain the limits of portability.

✓ *Schmidt-Cassegrains*

Advantages — They're easy to use, are compact and portable, have sufficient aperture and focal length for lunar and planetary photos, and have readily available photo accessories for every type of astrophotography. The f/6.3 models have good speed for deep-sky photography. The Schmidt-Cassegrains are probably the best all-round choice for astrophotography dabblers.

Disadvantages — The fork mounts can be shaky; the focus adjustment can be sloppy; curvature of field throws stars at edges out of focus; speed is slow in f/10 models, though a telecompressor lens accessory can convert these to f/5, but with a limited field.

Outstanding examples — Celestron Ultima 8 (the hefty forks, built-in power supply and periodic error correction circuit are excellent); the Meade Premier Series Models 50 or 56 — choose the f/6.3 model if deep-sky photography is your sole passion; otherwise get the f/10 version.

Is Astrophotography on the Rise?

Amateur astronomy goes through cycles of fads and fashions. Interest in astrophotography seemed to reach a peak in the 1970s but then declined. The 1980s saw the rise of the Dobsonian telescope. It represented a return to low-tech, no-frills observing, uncomplicated by drives, cameras, equatorial mounts, guiding accessories, and all the other trappings of the photographer. But after several years of abstinence from technology, backyard astronomers seem to be swinging back the other way. Even loyal Dobsonian fans are putting their scopes on Poncet tracking platforms to follow the stars. And yes, some (gasp!) are even taking pictures through their telescopes.

The advent of ultra-fast films like Konica 3200 has brought exposure times down to tolerable levels, enticing more people back into astrophotography. In addition, the demands of today's educated and discriminating buyers have prompted manufacturers to produce a selection of high-quality instruments. Combine the two — the film and the equipment — and you have all you need to get some great photographs you can show with pride. □

MAGNIFICENT ORION

Filled with bright and beautiful nebulae,
Orion is a constellation not to be missed — especially its gem, M42

by Alan Goldstein

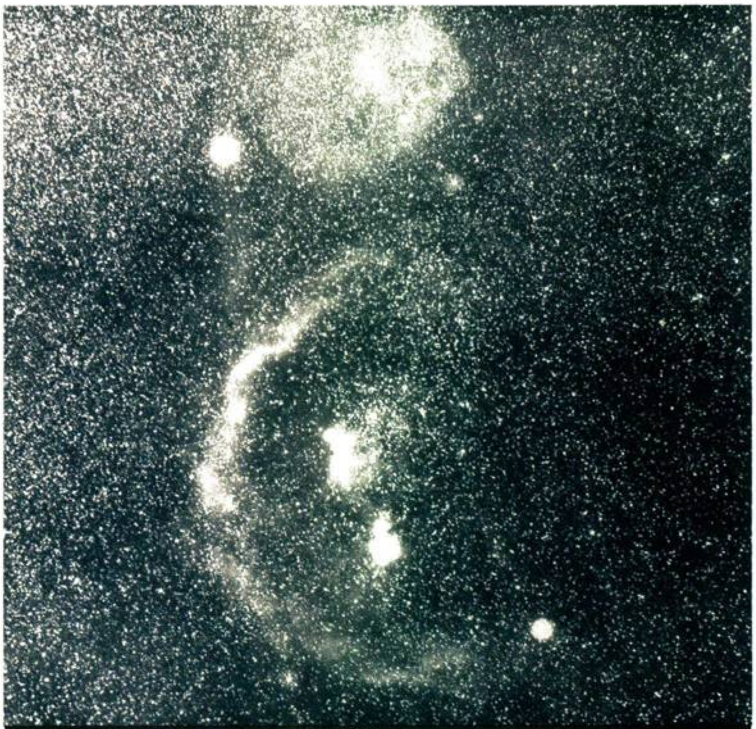
Orion the Hunter is everybody's favorite winter constellation. Orion's star-studded figure contains more 1st-magnitude stars than any other constellation. Its distinctive form, like that of the human frame, is instantly recognizable. Straddling the celestial equator, Orion is well placed for observers throughout both hemispheres.

The most famous inhabitant of Orion is visible to the naked eye as a 4th-magnitude fuzzy patch in Orion's sword. The Orion Nebula (M42, NGC 1976) is an enormous complex of bright nebulosity and dust that is the closest star-making machine to our solar system. Its distance is not precisely known, but the nebula is thought to be between 1,000 and 1,900 light-years away. Consequently, its diameter is between 30 and 45 light-years. The collected mass of M42 is equal to approximately 10,000 Suns.

The Orion Nebula represents the pinnacle of deep-sky observing for amateur astronomers observing in mid-northern latitudes. It is unquestionably the most spectacular emission nebula visible to Northern Hemisphere observers. The nebula spans 85' by 60' and is visible in telescopes as a bright core of nebulosity surrounded by a hauntingly beautiful envelope of faint greenish light arranged in a double-fan shape that fills an entire low-power field. As large and delicate as it appears telescopically, long exposure photography reveals the M42/43 complex is the bright core of an immense expanse of celestial gas that is faintly painted across the region of Orion.

The Orion Nebula has fascinated telescopic observers for nearly four centuries. The first telescopic observation of M42 was made by Nicholas Peiresc in 1611, more than 100 years before Charles Messier included it in his famous catalog of nonstellar objects. Oddly enough, M43, a comma-shaped nebula separated from the larger M42 by a rift of dark nebulosity, was not observed until 1731. The first attempt to sketch the complex beauty of the Great Nebula was that of Christiaan Huygens in 1656. Huygens subsequently called attention to the star system Theta Orionis, now called the Trapezium, in the heart of the nebula. William and John Herschel sought inspiration for their mammoth surveys of the sky by studying complexities of the Great Nebula. In 1880 Henry Draper ensured a key role for the Orion Nebula in the transformation of professional astronomy when it was the first deep-sky object captured on film.

M42
Size 85' by 60' by Ben Mayer



Orion
by Gregory Field

Today, with the advent of large aperture telescopes, M42 has not been lost in the deep-sky shuffle. It is still turned to in awe by more observers than any other deep-sky object. It is a favorite for observers with binoculars, and is spectacular with any telescope. M42 offers something for every instrument: Wide-field, low-power instruments can trace the nebula's faint outer extensions. High-power or long focal-length telescopes can study the intricate detail and texture of M42's innermost regions. Whether you are observing at 7x or 350x, there is always something fascinating to see in M42.

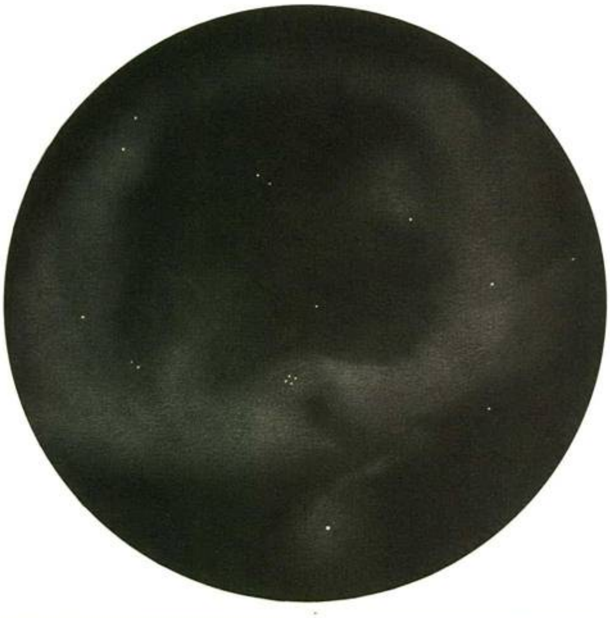
M42 offers numerous observational challenges.

How much nebulosity can you see? Can you detect color? What is the faintest star observable within M42? How many of the variable stars can you see? Are any double stars visible? What you see with your telescope will be determined by many factors.

As an exercise in determining what you see, consider making a sketch of M42. Don't worry about how artistic it looks — you only have to show it to yourself. Over several weeks, sketch it several times. Your sketching ability may not improve, but your ability to see more detail will. Eventually, given a telescope of sufficient aperture, the incredible detail in the gas cloud will exceed your mind's ability to soak up and process the flood of photons you will see. The result is an observation you will never forget. Yes, the nebula is impossible to draw and is significantly more dazzling than the best photograph ever made.

The powerhouse of the Great Nebula is a cluster of very young (approximately 30,000 years old) stars in the center of the cloud. The lower energy photons of light we see are given off as a result of the high-energy ultraviolet radiation given off by the stars and illuminating the gas by fluorescence.

What color is M42? Why doesn't it appear red as it does in photographs? The answer lies within our own eyes. The human eye is not sufficiently sensitive to pick up the red glow emitted by the hydrogen gas in nebulae like M42. While the nebulosity is mostly hydrogen gas, also present are helium, carbon, oxygen, nitrogen, sulfur, and neon. Our eyes pick up the green glow of doubly ionized oxygen — it isn't the most abundant element in the nebulosity, but it emits photons with sufficient energy for our eyes to detect. Consequently, observers capable of detecting color in the Orion Nebula are most likely to see a greenish glow. The intensity and hue varies with aperture and eye sensitivity. Some observers report the Great Nebula as pale green or greenish gray in color. Others call it pea green. With a 20-inch f/5 telescope, it is best described as the green color of fresh spring leaves. A few experienced observers see a light reddish hue in the outer streaks.



M42
8-inch f/5 reflector at 55x Sketch by Phil Harrington

John Herschel, the first observer to do an in-depth study of M42, named several features in the nebula. Some of these regions may seem familiar, even if the names are odd. For instance, the bright central area surrounding the Trapezium was named *Regio Huygeniana* after Christiaan Huygens, whom Herschel mistakenly thought discovered the Orion Nebula. The dark nebular protrusion into the area near the Trapezium was called *Sinus Magnus*, the Great Gulf. In his 1844 *Bedford Catalogue*, William Henry Smyth called this area "the fish's mouth." The so-called arms of the nebula that trail to the south and east were broken into two tendrils, *Proboscis Major* and *Proboscis Minor*, the Greater and Lesser Trunks. The darkness between it was dubbed *Regio Messieriana* after the French comet hunter Charles Messier.

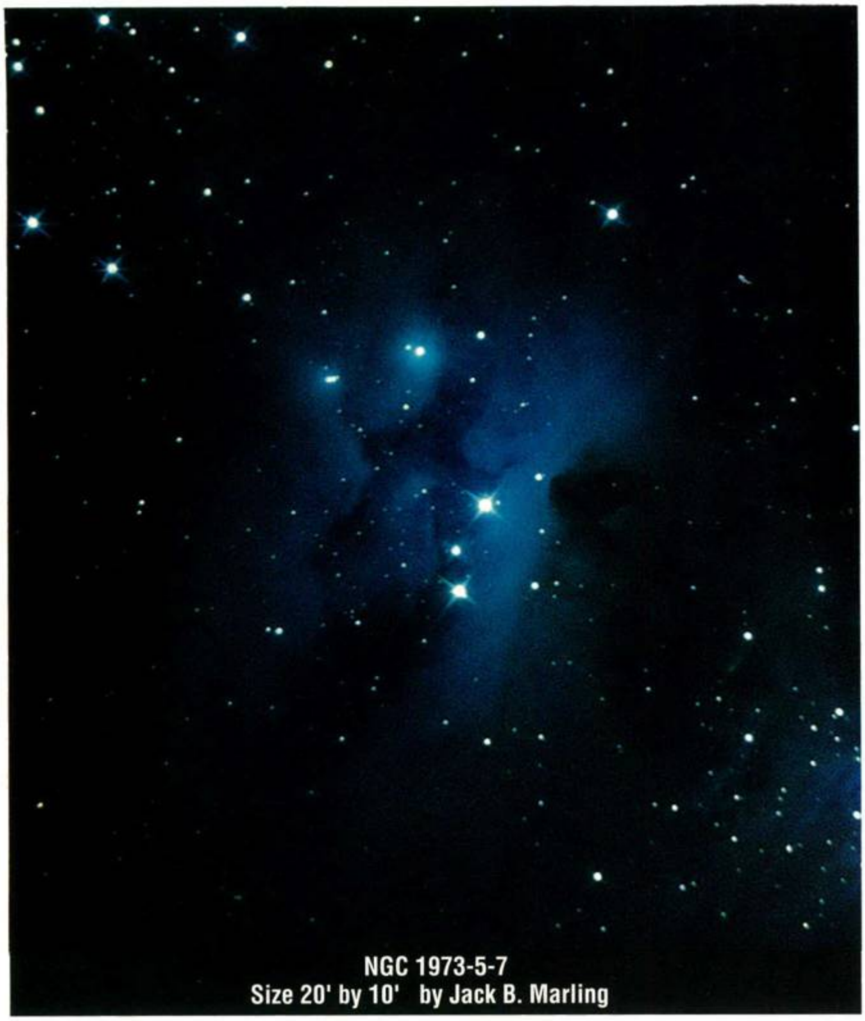
M43 is the comma-shaped cloud of gas that is visually separated from M42 by a wedge of dark nebulosity. An 8th-magnitude star in the center causes this part of the nebular complex to glow. Astrophotos show that M43 is part of the larger M42 cloud and that the separation is merely an illusion produced by line of sight.

The **Trapezium**, Theta[1] Orionis, is one of the best known multiple star systems. It is easily resolvable with small instruments. The four stars are designated A, B, C, and D. Star C is the brightest at 5.4 magnitude, while star D is second at 6.3. The other two are variable stars. Star A is an eclipsing binary. Normally at magnitude 6.8, it fades one magnitude every 65.4 days. Star B is an eclipsing binary normally glowing at 7.9 magnitude, with a period of 6.5 days. The four members of this multiple star system are hot and very young: their spectral types are either type O or B. These stars cause much of the Great Nebula to glow.

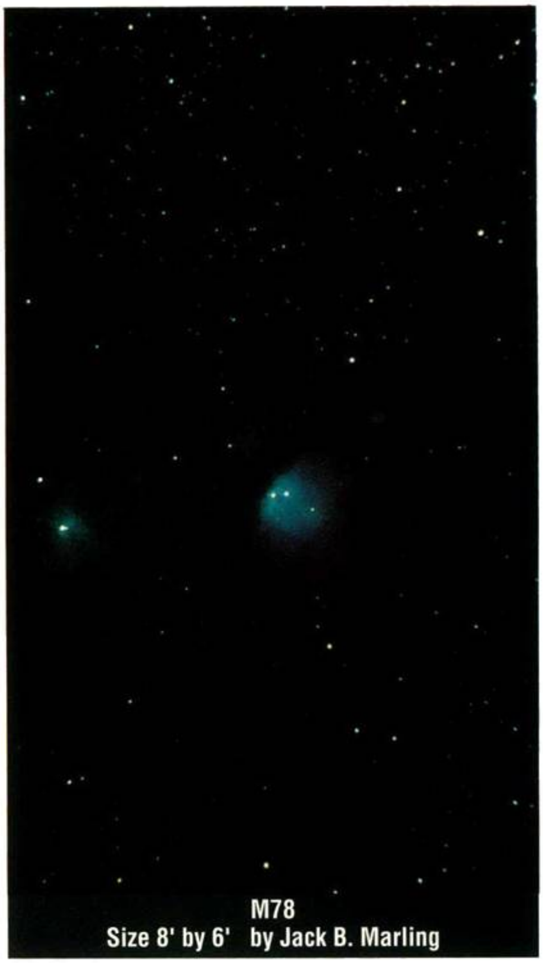
There are other stars around the Trapezium that offer a challenge to observers. About 4" north of star A is an 11th-magnitude star designated E. It was discovered by F. G. W. Struve in 1826. Some 4" southeast of C lies star F, an 11th-magnitude star discovered by John Herschel in 1830. Star G was discovered by Alvan G. Clark in 1888. It is located about 6" west of star D. At 16th magnitude, the G component is a challenge for larger instruments, made especially difficult by the bright glow of the nebula. In 1888 E. E. Barnard discovered the 16th-magnitude double star designated H, whose components are separated by 1.3". It lies west of C and south of A, forming the vertex of a right triangle with those two Trapezium members.

Theta^2 Orionis lies a few arcminutes southeast of the Trapezium, just outside of the central nebular glow (the Huygenian region). Theta^2 is a wide double star with a separation of 52.5". The brighter star glows at 5.4 magnitude, the companion at 6.8. This easy pair is usually ignored by observers reveling in the beauty of the Great Nebula.

Less than 1° north of the Orion Nebula are two other deep-sky wonders. **NGC 1973-5-7** is a single nebula, each NGC number representing a bright area excited by a bright star. In photographs, the nebula is bordered to the south by an irregular lumpy dust cloud. This nebula is difficult to see under most observing conditions but is visible with an 8-inch telescope under very dark skies. The most difficult patch, NGC 1977,



NGC 1973-5-7
Size 20' by 10' by Jack B. Marling



M78
Size 8' by 6' by Jack B. Marling

involves the 4th-magnitude star 42 Orionis. The star's light floods the field, making the nebula much more difficult to observe than the other two parts. The Y-shaped rift in the center of the nebula is very difficult to see. Color photographs reveal that this nebula is a blue color, indicating that it is reflecting much of the starlight.

About 30' north is the coarse open cluster **NGC 1981**. This cluster of less than fifty stars lies within an area about 45' across. This group is best seen with low power. Webb called this cluster "a grand neighborhood" and a "brilliant field containing Struve 750 and Struve 743." These double stars glow at magnitudes 6 and 8 and 6.9 and 8 respectively and have separations of 4.3" and 1.8". The cluster is somewhat elongated, consisting of two rows of stars with a sprinkling of others in the field. NGC 1981 is best observed in 3-inch to 6-inch scopes at relatively low power.

Several deep-sky objects lie south of the Orion Nebula. **NGC 1980** is an emission nebula that is part of the complex in Orion's sword. Like NGC 1973-5-7, NGC 1980 is a pale, ghostly cloud barely visible with most telescopes. It is easy to locate, as it surrounds the bright star Iota Orionis. You will need clean, well-collimated optics 8 inches or more in diameter to pick up this faint wisp of nebulosity. Use averted vision by scanning the field and let the sparse light from NGC 1980 hit the light-sensitive rods in your eyes. Your success in finding this object will be much more likely if you use averted vision.

Our last featured object is **M78** (NGC 2068), a bright, pretty reflection nebula. M78 consists of two nebular patches, the brightest glowing at 10th magnitude. The two patches are separated by a distinct dark lane. With a small telescope, you'll need a dark, moonless night to detect this dark lane.

Long-exposure photos reveal a substantially more complicated scene than is visible in a telescope. Webb called M78 a "singular, wispy nebula." Smyth recorded the nebula as "a singular mass of matter trending from a well-defined northern disk into the south-following quadrant, where it melts away." Many observers think M78 resembles a comet with a double nucleus and a short tail fanning away. The double star in the heart of M78 glows at about 8.2 magnitude.

Don't miss Orion this winter. Not only is it a bewitching sight to the naked eye on frosty nights, but it also offers a beautiful array of deep-sky objects for your telescope. Delve deep into studying the intricacies of M42, one of the most fantastic objects in the sky. But don't neglect Orion's other deep-sky wonders, hot spots in an intricate network of nebulosity that covers the entire constellation. □

Alan Goldstein is curator of science at the Museum of History and Science in Louisville, Kentucky. He is also the founder and national coordinator of the National Deep Sky Observer's Society.

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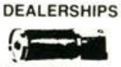

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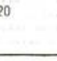

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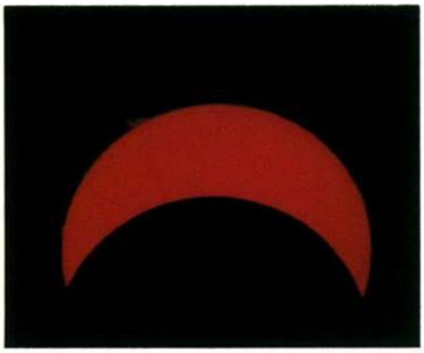
JULY 21'S MAGNIFICENT ECLIPSE

July's solar eclipse was greatly enjoyed by dozens of readers who submitted observations, particularly observers on the west coast who saw a partially eclipsed Sun.

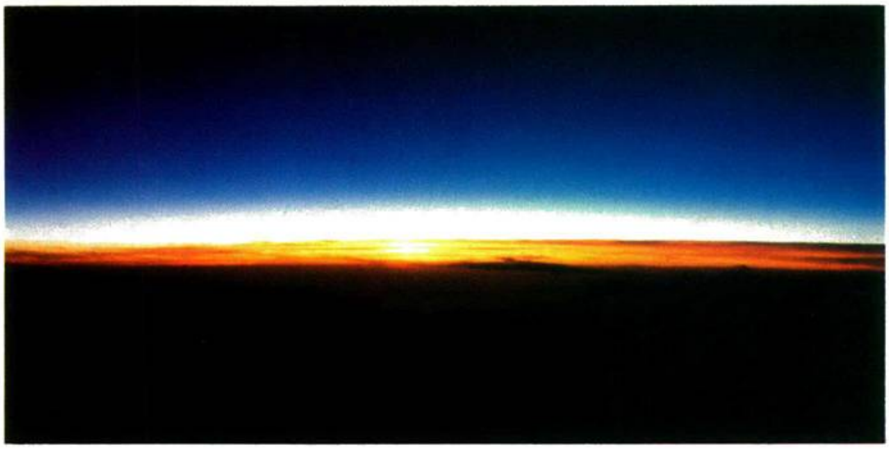
Ernie Piini watched the event from the 3,000-foot level of Mount Diablo, which overlooks the San Francisco Bay area. "As the eclipse progressed my friend Harvey Sherman and I were surrounded by about thirty curious campers who shared our telescope. We had a clear view of the event even as fog covered the San Francisco area below us."

The greatest thrill for Piini came as the Sun set. "The Sun looked like a football helmet with a bite taken out of it," says Piini. "My greatest thrill was seeing the so-called blue flash as the Sun set. It lasted about three seconds and I was fortunate enough to capture the event on film."

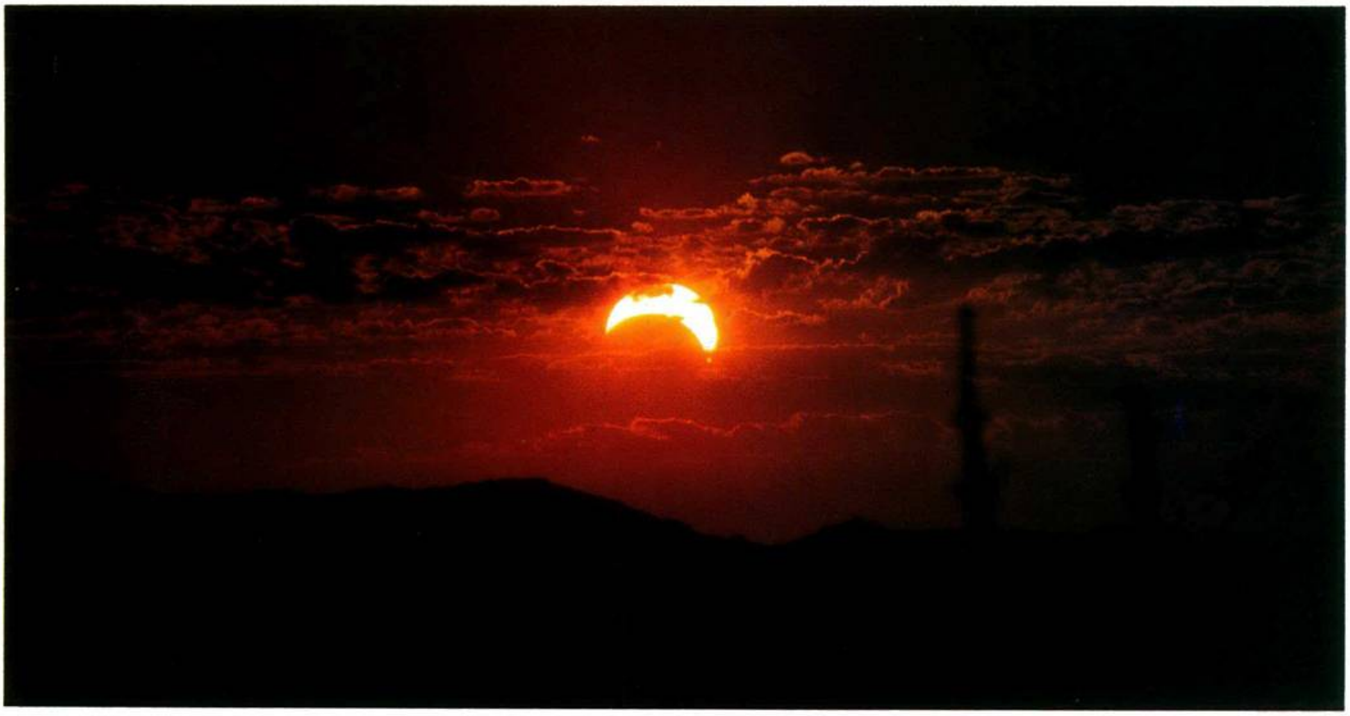
Air Force pilot Thad Fuller of Rocklin, California, viewed the Moon's shadow as it swept over Earth from a U-2 reconnaissance plane. "The planes fly at altitudes above 70,000 feet, which I greatly enjoy because I'm an astronomy buff," says Fuller. "Sometimes we get spectacular views, as was the case with the



THE PARTIALLY ECLIPSED SUN appeared like a ruddy crescent Moon to observers in British Columbia. Photo by Jack Newton, who used a hydrogen-alpha viewer.



THE MOON'S SHADOW swept over Earth's surface creating an eerie, artificial night. U.S. Air Force reconnaissance pilot Thad Fuller photographed the terminator from his U-2 aircraft.



JULY 21'S SOLAR ECLIPSE was visible as total from Finland and Siberia and partial from other areas, including the west coast of the U.S. Photo by Clark B. Snure.

WHAT A DAY FOR AN ECLIPSE!

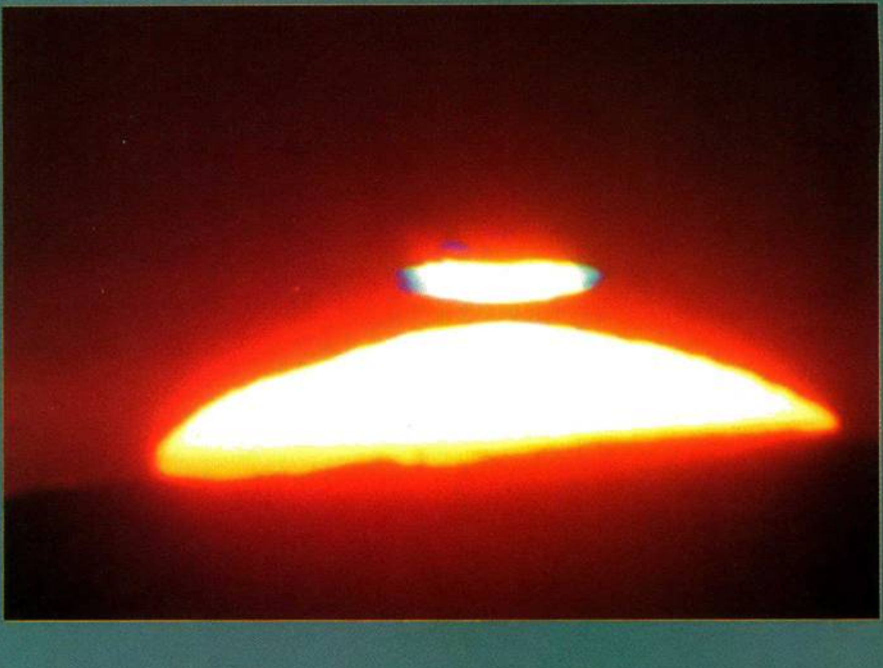
When Roy Gephart stood near Prosser, Washington, in the early evening of July 21, 1990, it wasn't clear that he would capture the solar eclipse. Thick clouds rolled along the crest of distant mountains, and the Sun was setting. Somehow, though, it turned out to be a good day for an eclipse. The clouds parted sufficiently for Gephart to photograph the spectacular scene. The result is this month's $100 "Best Astrophoto" award winner (right). Gephart used a 300mm lens at f/16, Kodachrome 64 film, and a 1/30-second exposure.

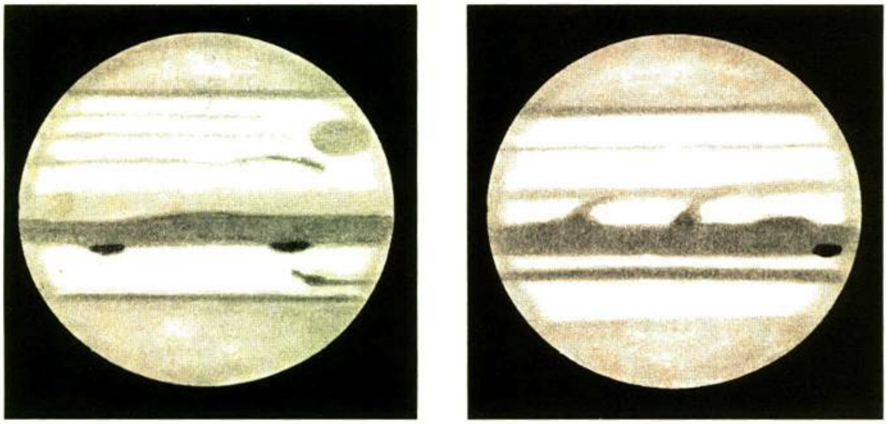
As the eclipsed Sun set over Mount Diablo, California, Ernie Piini captured the "blue flash," an optical phenomenon produced by refraction (opposite, below right). Piini used a C90 3.5-inch f/15 telescope, Ektar 25 film, a neutral density filter, and a 1/60-second exposure.

With all of the excitement generated by the solar eclipse, some observers nearly forgot about other solar system events. During early August Comet Levy brightened to naked-eye visibility as it slowly moved through the constellation Pegasus. On the morning of July 28 Arizona astrophotographer Chris Schur captured Levy on film with his 14-inch f/5 reflector, hypered Tech Pan, and a 15-minute exposure (below).

The following morning on a mountaintop half a continent away, Paul Shulins recorded an impressive aurora display witnessed by hundreds of observers (below right). Shortly after midnight on July 29 this aurora danced and hovered about the Big Dipper as appreciative crowds at Stellafane in Springfield, Vermont, watched intently. Shulins used a 50mm f/2.8 lens, Kodacolor 400 film, and a 25-second exposure.

On July 5 Nelson Falsarella of Sao Jose do Rio Preto, Brazil, used his CCD video camera and an 8-inch f/6.5 telescope to record the Moon as it occulted Antares (opposite, below left). Falsarella recorded the image on tape, found the best frames, and photographed stills from his video monitor to produce photographic prints.





THEN YOU DIDN'T SEE IT, NOW YOU DO: In late February Jupiter's missing North Temperate Belt began to reappear; now it is plainly visible. The planet's South Equatorial Belt is still missing, however. Sketches made on February 25 and May 22, 1990, by Jose Olivarez.

Moon's shadow sweeping over the surface of Earth."

Nadia LaFoy of Yellowknife, Northwest Territories, reported that because of forest fires in the Yukon and in Alaska, she was able to "view the solar eclipse with the naked eye. I took some photos with my camera and did not have to use a filter because of the density of the smoke."

Jacques Guertin of Newark, California, viewed the eclipse from the island of Atka in the Aleutians. Guertin and eight other eclipse chasers climbed the island mountains and waited for the eclipse. Unfortunately the group was clouded out. "It was a strange feeling to look at clouds darkened by the Moon's shadow, knowing of the awesome drama that must be occurring in the sky above the clouds," says Guertin. "But we will be present for the next eclipse."

JUPITER'S NORTH TEMPERATE BELT REAPPEARS

Jose Olivarez, Jupiter Recorder for the Association of Lunar and Planetary Observers, reports that the giant planet's North Temperate Belt has returned to prominence. "Additionally, observers discovered rapidly moving spots in Jupiter's North Temperate Current 'C,' and have monitored the appearance of a light-orange colored veil over the planet's Equatorial Zone," says Olivarez.

The North Temperate Belt was last prominent in 1986 but faded in 1987 and was only visible as a thin, faint band during 1988 and 1989, according to Olivarez. The NTB's resurgence began in late February 1990 after the appearance of a rapidly moving white spot in the adjacent North Temperate Current 'C.' Throughout March and April dark spots and segments of the NTB appeared until the NTB was completely formed as a continuous "new" belt by the end of May 1990.

Jupiter continues to delight observers with active phenomena. — *David J. Eicher.* ☐

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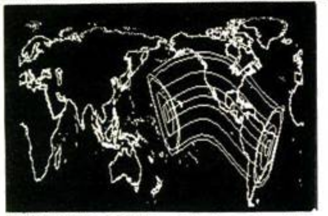

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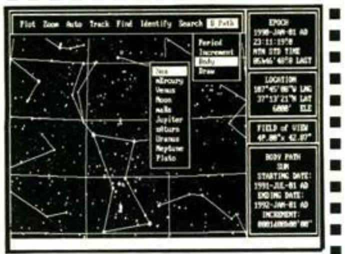

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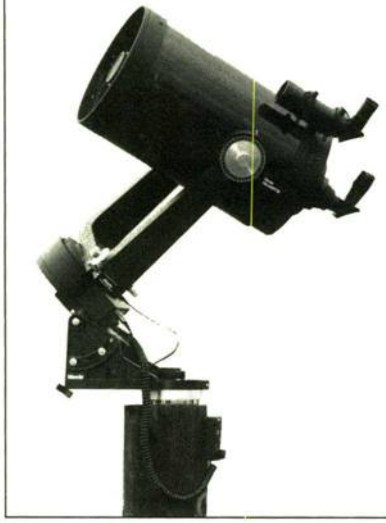
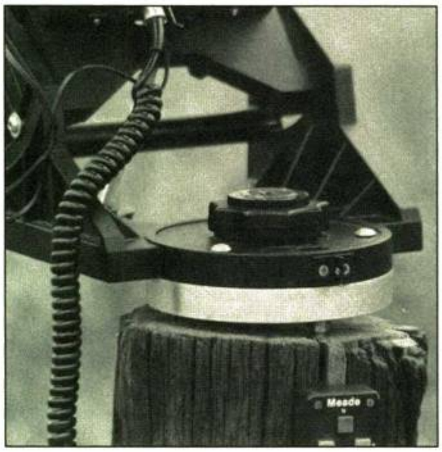
UNI-POD, 2055 Marshall Drive, Valparaiso, IN 46383; $63.00. Shipping included.





2 Swift Instruments Micron Porro Prism Binocular

The Swift Model 801 is a 10x25 porro prism binocular featuring barium crown prisms and multi-coated optics. It weighs 9.4 ounces and focuses down to 14.8 feet. A new 6 -12x23mm zoom binocular (the Model #803) is also being offered. A 48-page full-color catalog of all Swift Instruments products is also available.

Swift Instruments, Inc., 952 Dorchester Avenue, Boston, MA 02125; (617) 436-2960. Model 801: $123.85; Model 803: $199.50. Catalog: $5.00.

3

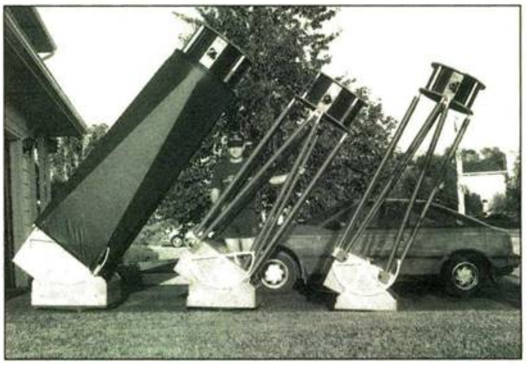
Celestron Coma Corrector

This accessory is for Newtonian telescopes with f/ratios of f/4 to f/6. It eliminates distortion of star images near the edge of the field due to coma. The *Celestron Coma Corrector* fits 1-1/4-inch and 2-inch focusers and off-axis guiders and can be used both visually and photographically. The optics are multi-coated on all air-to-glass surfaces.

Celestron International, 2835 Columbia Street, P.O. Box 3578, Torrance, CA 90503; (800) 421-1526 or (213) 328-9560 (8 a.m. to 4 p.m. Pacific Time). $330.00.

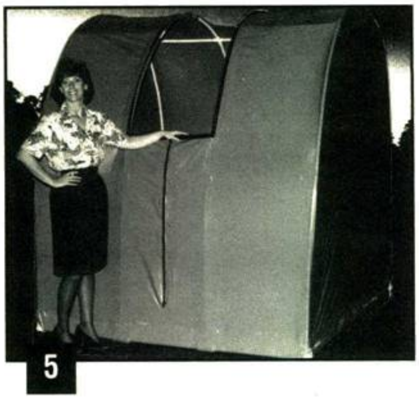
4 Obsession Telescopes

These giant altazimuth telescopes feature an award-winning design. Standard items include: 2-inch thick Galaxy Optics primary mirror, 8-point stainless steel flotation cell with 12-volt cooling fan, welded steel tailgate, cabinet-grade Baltic Birch construction, large, detachable maple handles with pneumatic wheels, solid cast aluminum side bearings, quick release cam action truss assembly, dual-speed 2-inch Astrosystems focuser, and a Novak secondary support. Assembly time for the entire telescope (one person working without tools) is claimed to be five minutes. 20-inch f/5 and 25-inch f/5 models available.



Obsession Telescopes, 923 Stoney Road, Lake Mills, WI 53551; (414) 648-2327 (9 a.m. to 5 p.m.). 20-inch (in stock): $4,295.00; 25-inch (12 weeks delivery): $8,895.00. Send $1.00 for brochure.

This department presents new product announcements issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.



5

Super Dome

This portable dome is made of polyvinyl nylon rated at 1,000 lbs. tensile strength per square foot. The *Super Dome* features an extended opening for viewing beyond the zenith, a Velcro™ adjustable shutter, and frame components made of PVC tubing. An optional roller system is available to aid in rotating the entire structure. Two sizes of Super Dome are available: the SD-6 for SCT and Newtonian telescopes up to 10 inches and Dobsonians up to 13 inches, and the SD-8 for telescopes up to 14 to 17 inches.

Ace Dome, Inc., 3186 Juanita, Las Vegas, NV 89102; (702) 873-5790. SD-6: $298.00; SD-8: $498.00. Shipping extra. Roller Rotation option: $65.00.

6

Noctilume PL-1 LED Flashlight

Using a new red light-emitting diode that is bright and efficient, the *Noctilume* flashlight will operate for a claimed 80 hours on one set of two AA batteries. The body is made of rugged ABS plastic. The LED is available separately for users who wish to retrofit other flashlights that use incandescent bulbs. All flashlights and bulb replacements are also available with an ultra-bright LED, three times brighter than the standard unit.

Noctilume, P.O. Box 63, Harbor City, CA 90710. PL-1 flashlight: $10.95; LED bulb replacements: $5.95; ultra-bright option: add $3.00. Prices include shipping and handling. Also available through Lumicon and Scope City. Brochure available.

7

Black Forest Observatory Products Catalog

The 1991 edition of the Black Forest Observatory catalog features hundreds of science and astronomy products, including educational and classroom items, telescopes, microscopes, space music CDs and tapes, slide sets, overhead transparencies, videos, posters, science software, and books. The Black Forest Observatory is a non-profit independent educational corporation.

Black Forest Observatory and Science Resource Center, 12815 Porcupine Lane, Colorado Springs, CO 80908; (719) 495-3828. Catalog is free.

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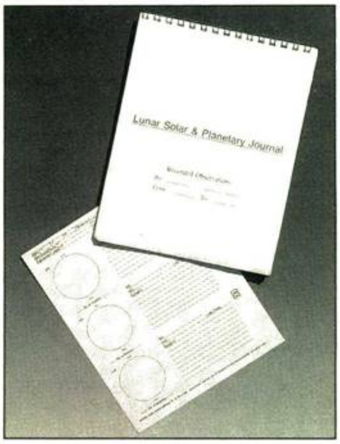

8

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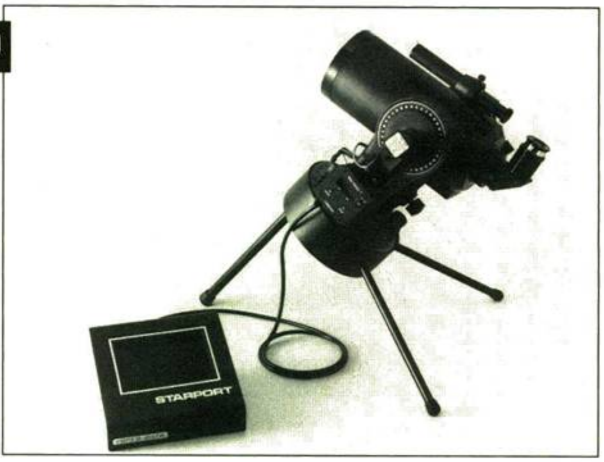
Celestron International, 2835 Columbia Street, P.O. Box 3578, Torrance, CA 90503; (800) 421-1526 or (213) 328-9560 (8 a.m. to 4 p.m. Pacific Time). $558.00.

10



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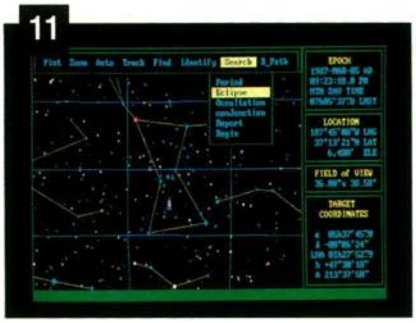
A series of menus accessed via a touchscreen allows the user to select the sky view and retrieve information. Users can select objects by type and magnitude range so only those objects of interest are displayed. An optional interface allows *STARPORT* to track along with a telescope, reading the telescope's position from encoders on the RA and declination axes. This allows the user to use the *STARPORT* to locate objects.

The *STARPORT* can be ordered by itself or with the telescope interface. Those who already own a Lumicon Sky Vector™, Celestron AstroMaster™, or JMI DSC-MAX™, can have these units retrofitted to connect to *STARPORT* , with the *STARPORT* utilizing the positional signals from the encoders already in place on the telescope.

Opto-Data, 600 Mariners Island Boulevard, #36, San Mateo, CA 94404; (415) 377-0211. Basic STARPORT: $895.00; STARPORT with telescope interface: $1295.00; STARPORT retrofitted to Sky Vector, AstroMaster, or DSC-MAX: $1095.00 (users must ship their digital setting circle control unit to Opto-Data for retrofitting). Write for brochure.

11



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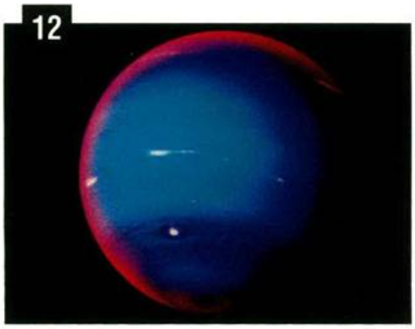
Zephyr Services, 1900 Murray Avenue, Pittsburgh, PA 15217; (800) 533-6666 or (412) 422-6600 in PA. $149.95 plus $3.00 shipping. Free catalog of astronomy software available.

12



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A DEEP-SKY GUIDE IN YOUR POCKET

Smart Chart II, (Roger W. Tuthill, Inc., 11 Tanglewood Lane, Mountainside, NJ 07092; (800) 223-1063, FAX (201) 232-3804), $195.00.

Similar to a pocket calculator in size and weight, Smart Chart II is an electronic deep-sky reference guide. Its red LED display gives the user quick access to the coordinates, magnitudes, and object types for all the Messier and NGC objects and to a convenient set of 19 reference or calibration stars. The original Smart Chart suffered from a sharp-edged metal case, a poor instruction manual, errors in the data, and only six alignment stars in its database. In addition, the epoch was 1975. The new version corrects all these flaws, including updating the positional epoch to 2000.

The Smart Chart is not a digital setting circle device; it does not connect in any way to your telescope. You look up an object's coordinates with the Smart Chart, then dial them in with your setting circles, either analog or digital.

A few minutes' practice with Smart Chart II will make you quite comfortable with its use. The slide switch on the right is the on/off switch and the button to the left at the top of the case "toggles" the display between its two modes. The first mode shows an object's catalog number, class, and magnitude. The other mode shows the current object's right ascension and declination. The Up/Down buttons scan rapidly through the database in jumps of approximately 100 objects. The Left/Right buttons move through the database one object at a time. When turned off, the Smart Chart remembers where you were so you can resume searching from where you left off.

You can also select the desired limiting magnitude (from 8 through 18) and which types of objects you wish to display as you step through the NGC database. The Messier database does not have this selective search option. You may include one or more of the following types in your search for NGC objects: open clusters, globular clusters, diffuse nebulae, planetary nebulae, clusters with nebulosity, galaxies, and unverified southern objects.

As an example, I set the limiting magnitude at 18 and selected only globular clusters as my search objects. I compared its output with the globular clusters listed in the *NGC 2000.0* computer database. The only object for which there was a positional disagreement was NGC 1841. The error was seven minutes in right ascension. Smart Chart reports R.A. to the nearest minute and declination to the nearest tenth of a minute. I detected no rounding errors in object position in any of the approximately 700 objects I checked.

I did find a systematic error in reporting magnitudes. It appears that when the *NGC 2000.0* database was entered into the memory chip for Smart Chart II, the programmer truncated, rather than rounded, the magnitude data. Roger Tuthill has assured me that this will be corrected in the next upgrade. In the meantime, users should be aware that Smart Chart's magnitudes can be brighter than those listed in the *NGC 2000.0* by up to 0.9 magnitude. In most cases, magnitudes are within 0.5 magnitude.

In addition to the check of globular clusters, I generated a random set of 540 NGC objects and then carefully compared the Smart Chart database with the computerized *NGC 2000.0* database. I again found a systematic truncation error in some of the magnitudes but detected no positional errors. As a result of this random testing, I am satisfied that the positional accuracy of Smart Chart II is comparable to that of *NGC 2000.0*. I am delighted with Roger Tuthill's much-improved version of a very useful observing tool. — *Tom Mote* ☐

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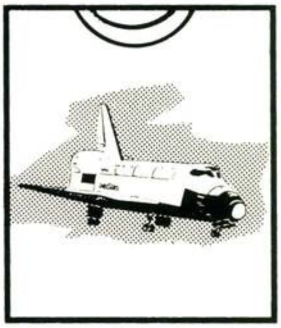

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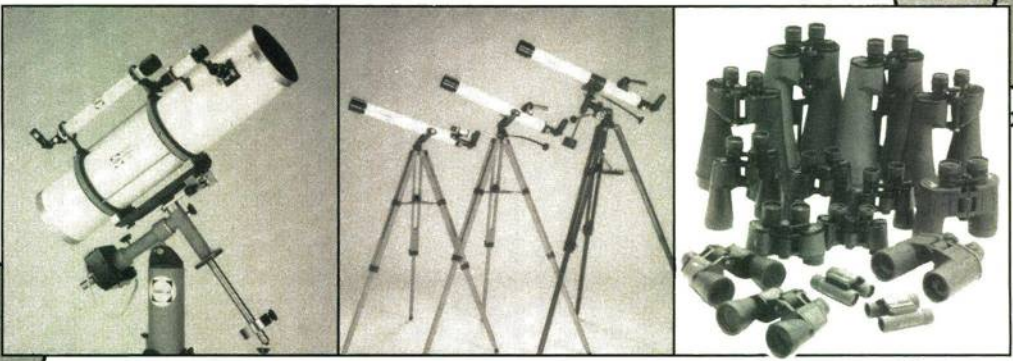

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Astronomy Books

A GOOD BOOK PUT TOGETHER TOO QUICKLY

The Practical Astronomer, by Brian Jones and Stephen Edberg, (Simon and Schuster, 1990), ISBN 0-671-69303-4 (pbk), 160 pages, hardcover, $24.95; paperback, $14.95.

Amateur astronomer Brian Jones and editor Stephen Edberg have packed almost everything a novice stargazer needs to know into this book — but to get the most out of it you have to be able to decipher the hard-to-follow language they use in some passages. Most of the book, however, is clear and easy to understand, and the text is complemented by fine photos, artwork, and star charts. The overall level of presentation is non-technical.

The book begins with an illustrated, factual survey of the universe. It starts at the solar system and ends with clusters of galaxies. The second half of the book is observational and deals with the celestial sphere, cnoosing binoculars, making a Dobsonian mounting, astrophotography, building an observatory, and so on. Observing guides to the Moon, planets, stars, nebulae, and galaxies follow. The last part provides 14 star charts showing stars to 6th magnitude, the Milky Way, and the brighter deep-sky objects. A glossary, catalogue, and index round out the book.

The star charts are good and work pretty well under red light. (The blue sky becomes too dark a gray to let the black object identifications show well, except in the lighter blue areas that mark the Milky Way.) The charts are crammed with details and show the major stars for each constellation linked in the usual "connect the dots" fashion. Each chart is accompanied by a one-page discussion of what to look for, and eyepiece views (and photos) of objects of interest accompany most charts.

I noted some problems that flaw this otherwise good book. These include a too-brief discussion on how to take astrophotos (although it is enough to get you started). The topographic map of Venus is reproduced too small, even if one acknowledges that it can serve only armchair astronomy. In the opening two-page section on the solar system, there is no mention of Pluto. The lines that identify craters on the Moon photos are about an eighth-inch out of register.

The photos accompanying the discussion of variable stars ask the reader to locate the eclipsing binary Algol in a field of stars in one photo and the famous variable Delta Cephei in another. But I doubt any novice could do that without having something (an arrow, say) to locate the objects in the photos. In another instance, the text for the photos of the long-period variable star Mira tells the reader to compare the left-hand photo to the right-hand photo, but the photos are placed one above the other and, again, there's nothing to point out the feature of interest.

When I first thumbed through this book and skimmed parts of the text, I felt it would be a marvelous work for a novice to have. (Even the paperback edition has a durable sewn binding!) Unfortunately, upon a closer reading, I found the problems I mentioned and many other minor ones all detracting from an otherwise good book.

I cannot give the book the high recommendation I'd like to. On the other hand, with a little more care in production, a second edition could easily correct the flaws and turn it into the kind of work you could put unreservedly into the hands of a novice stargazer. It's too bad this version's efforts suffered from what appears to have been a rush job to get the book into print. — *Robert A. Garfinkle.*

Observing

Bright Star Atlas 2000.0, by Wil Tirion, (Willmann-Bell, 1990), ISBN 0-943396-27-1, 34 pages, paperback, $9.95.

Covering the whole sky in 10 charts, Tirion's *Bright Star Atlas* plots nearly every star brighter than magnitude 6.5. Six wide-angle finder charts show you which part of the sky is visible at any time in the year. The atlas also contains lists of objects (galaxies, clusters, nebulae, variable stars, and so on) visible in small telescopes. The paper cover is heavy laminated stock and dew-resistant. (All the material in the *Bright Star Atlas* was also published in *Men, Monsters, and the Modern Universe* by George Lovi and Wil Tirion.)

Star and Planet Spotting, by Peter Lancaster Brown, (Sterling, 1990), ISBN 0-8069-7268-8, 148 pages, paperback, $8.95.

This is a largely unchanged reprint of a work first published in 1974. (The changes consist of a table giving the ecliptic longitudes of planets at 10-day intervals from January 8, 1990, to December 27, 1999.) The bulk of the book is a simple and useful guide to sky watching with binoculars and small telescopes.

Astronomical Photometry, by Arne Henden and Ronald Kaitchuk, (Willmann-Bell, 1990), ISBN 0-943396-25-5, 396 pages, hardcover, $24.95.

This book is a thoroughgoing handbook and textbook that is essential reading for any observer (amateur or professional) who wants to make measurements of star brightnesses. It is a corrected reprint of a work first published in 1982.

Sundials, by R. Newton Mayall and Margaret W. Mayall, (Sky Publishing, 1989), ISBN 0-933346-60-3, 250 pages, paperback, $9.95.

Sundials tells you how to make many different kinds of sundials: traditional flat dials, equatorials, verticals, cylindricals, and so on. Because this is an unchanged reprint of a book published in 1973, the construction techniques are geometric instead of computational, although an appendix gives the basic formulae. The book is abundantly illustrated.

The Solar System

The Solar System, by Térèse Encrenaz and Jean-Pierre Bibring, (Springer-Verlag, 1990), ISBN 0-387-18910-6, 330 pages, acid-free paper, hardcover, $59.50.

Written by two European planetary astronomers, *The Solar System* is aimed at undergraduate students of planetology. It places more emphasis on atmospheres and particles and fields than the "hard rock" geology that a North American book would stress — which makes its perspective useful and interesting.

Catastrophes and Evolution: Astronomical Foundations, edited by S. V. M. Clube, (Cambridge University Press, 1989), ISBN 0-521-37420-0, 239 pages, hardcover, $44.50.

Twelve papers by astronomers and geologists working on impact phenomena examine the effects of large meteorite falls on Earth life. The papers were given at a meeting of the Royal Astronomical Society in September 1988.

The Origin of Comets, by M. E. Bailey, S. V. M. Clube, and W. M. Napier, (Pergamon Press, 1990), ISBN 0-08-03458-0 (paperback edition), 577 pages, paperback, $32; hardcover, $64.50.

"In truth, the subject of cometary origin is enormously complex, with links...[to] the origin of stars, nebulae, and planetary systems....Even now, there is no general agreement as to 'the' origin of comets." Although this book was written for professional astronomers, it contains much that is accessible to any layman interested in where comets come from. In addition, the historical section, roughly the first 150 pages, contains many period illustrations, several in full color. (In a nice touch, even the paperback edition has a sewn binding for durability.)

Voyager Grand Tour Suite, by Michael Lee Thomas, (Bainbridge Records, 1990), digital cassette tape or CD, booklet, TT=53:19, CD $11.98, tape $7.98.

Using the flight of *Voyagers 1* and *2* as a theme note, Thomas has written appropriately spacey music as a soundtrack. "I call my music 'soundscapes,'" says Thomas. "I want people to be able to put on a pair of headphones and go where they want to go with it."

Stars and Galaxies

Pulsar Astronomy, by A. G. Lyne and F. Graham Smith, (Cambridge University Press, 1990), ISBN 0-521-32681-8, 274 pages, hardcover, $69.50.

This survey, written for scientists and advanced lay readers, updates an earlier work by Graham Smith. It provides a balanced introduction to the wide variety of astrophysical processes now known to occur in pulsars and their immediate surroundings.

Stars and Galaxies, edited by Donald E. Osterbrock, (W. H. Freeman, 1990), ISBN 0-7167-2069-8, 184 pages, paperback, $11.95.

Books of reprints from *Scientific American* sit on the library shelves of most amateur astronomers and this new collection will also likely take a place there for many. The dozen articles date from 1979 to 1989, and cover such topics as William Herschel, molecular clouds, Epsilon Aurigae, pulsars, the Galaxy's central core, and supernova 1987A.

The Epoch of Galaxy Formation, edited by Carlos S. Frenk, Richard S. Ellis, Tom Shanks, Alan F. Heavens, and John A. Peacock, (Kluwer, 1989), ISBN 0-7923-0148-X, 445 pages, hardcover, $119.

This volume of professional papers originated from a workshop held in Durham, England, in July 1988, on galaxy formation in the early universe. Main sections review galaxy formation at various redshifts, gas clouds at high redshift, quasars, the evolution of galaxies and clusters, cosmic and x-ray background radiation, models, and the age of the Galaxy. Also included is "Galaxy Formation: The Board Game."

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Cosmology

Origins, by Alan Lightman and Roberta Brawer, (Harvard University Press, 1990), 561 pages, acid-free paper, hardcover, $29.95.

Lightman and Brawer interviewed 26 theoretical and observational cosmologists in an attempt "to explore the ways in which personal, philosophical, and social factors" entered into their work. The result is a fascinating behind-the-scenes look at how cosmologists choose the problems they work on and what they think about the trends in the field at present. Those interviewed include Fred Hoyle, Allan Sandage, Vera Rubin, Stephen Hawking, John Huchra, Margaret Geller, and Jeremiah Ostriker.

At the Edge of the Universe, by Alan Wright and Hilary Wright, (Ellis Horwood, distributed by Halsted Press and John Wiley and Sons, 1989), ISBN 0-470-21239-X, 236 pages, hardcover, $41.95.

At the Edge of the Universe presents the cosmos as it is understood by astronomers who probe its most extreme depths with telescopes and sensitive instruments. The Wrights report on the results of searches for high-redshift objects and the surveys of large-scale structure in a clear and unassuming way. A friendly style predominates, although the authors do fall back on graphs and equations when the going gets technical. But by confining their subject to the very distant universe and the search for high-redshift objects, the Wrights have written a book that bridges a wide chasm in popular cosmology literature.

General Astronomy

The Astronomer's Universe, by Herbert Friedman, (W. W. Norton, 1990), ISBN 0-393-02818-6, 359 pages, hardcover, $24.95.

An astronomer who was a pioneer in sending instruments above the atmosphere and into orbit writes an interesting layman's survey of modern astronomy, placing special emphasis on high-energy astrophysics.

Alice and the Space Telescope, by Malcolm Longair, (Johns Hopkins University Press, 1989), ISBN 0-8018-2831-7, 198 pages, acid-free paper, hardcover, $26.95.

Written before the *Challenger* disaster (which occurred nine months before *HST* was due for launch), this book for the general reader provides a detailed tour of astronomy as it reflects the problems the space telescope will study. Alice, who slipped in through a side door from Wonderland, stands for Everyman and feeds leading questions to advance the story, which is engaging and well-told.

First Contact: The Search for Extraterrestrial Intelligence, edited by Ben Bova and Byron Preiss, (NAL Books, 1990), ISBN 0-453-00720-1, 337 pages, hardcover, $19.95.

Twenty essays and two short stories focus on the subject of this book's title. The essay authors include Isaac Asimov, Arthur C. Clarke, Philip Morrison, Frank Drake, and Paul Horowitz; the fiction authors are Ben Bova and Stanley Weinbaum. Essays cover such topics as the politics of SETI, alien technology, alternative life designs, and the Harvard SETI project.

Time Travel, by John W. Macvey, (Scarborough House, 1990), ISBN 0-8128-3107-1, 204 pages, hardcover, $16.95.

Subtitled "a guide to journeys in the fourth dimension," this popular-level book provides an overview of the notion of time in modern physics as well as the ways (through the relativistic time-dilation effect, for example) that some form of time travel can occur.

Cosmic Life Force, by Fred Hoyle and Chandra Wickramasinghe, (Paragon House, 1990), ISBN 1-55778-266-0, 151 pages, hardcover, $16.95.

For several years, in the face of nearly total rejection from professional astronomers, Hoyle and Wickramasinghe have been advocating a theory which claims that life arrived at Earth from interstellar space and that freeze-dried "cosmic bacteria" continue to do so today. In this book (originally published in the United Kingdom in 1988) they expound their theory for the lay reader.

From Quarks to the Cosmos, by Leon M. Lederman and David N. Schramm, (W. H. Freeman, 1989), ISBN 0-7167-5052-X, 242 pages, hardcover, $32.95.

This well-illustrated book outlines for the general reader the equipment and instruments used by physicists and astrophysicists in their searches for Nature's secrets.

Poetry of the Heavens, compiled by Jerome J. Knuijt, (Mira Publishing, Rt. 1, Box 201, Hortonville, WI 54944), ISBN 0-9625168-0-5, 153 pages, paperback, $18.95.

Verse from such poets as Ruskin, Shelley, Longfellow, Whittier, and Whitman combines with that from many lesser-known authors in this anthology of which Mr. Knuijt writes, "I have compiled these poems because of the pleasures of body and spirit that have accompanied my reading and contemplation of them."

Reference

Handbook of Space Astronomy and Astrophysics, 2nd edition, by Martin Zombeck, (Cambridge University Press, 1990), ISBN 0-521-34787-4 (paperback), 440 pages, hardcover, $75; paperback, $34.50.

This handbook compiles in tabular form a great deal of numerical information, mostly for the professional scientist. Sections include general data; radio, infrared, ultraviolet, x-ray, and gamma-ray astronomy; relativity; plasma physics; and so on. Amateur astronomers will find several sections of the book useful, although more in a "Gee, isn't that neat?" sense than in a practical way. (Both editions have sewn bindings for durability.)

1990 Planetarium Sourcebook, edited by Barbara Williams, Gregg Williams, and Aaron Yakovetz, (Great Lakes Planetarium Association, 1989), 73 pages, paperback, $8. (Order from: Gary Sampson, Wauwatosa West High School Planetarium, 11400 W. Center St., Wauwatosa, WI 53222.)

Intended for persons running planetariums and developing shows for them, this sourcebook is a classified index (18 categories) of manufacturers and suppliers of star projectors, lenses, bulbs, slide sets, posters, telescopes, and the like. Each entry typically has the company's name and address, phone and fax numbers, and a short description of its product line. At the back of the sourcebook is an all-in-one index alphabetized by company name.

Celestial Computing, edited by David Eagle, (Science Software, 1990), ISSN 1044-9825, 120 pages approximately, paperback, $24.95. (Publisher's address: 7370 S. Jay St., Littleton, CO 80123-4661.)

This volume reprints volume 1 (1988-1989) of the quarterly periodical *Celestial Computing.* The contents include articles on calculating sidereal time, estimating times of lunar apogee and perigee, and calculating the visibility of satellites from a given location.

Compact Data for Navigation and Astronomy for the Years 1991-1995, by B. D. Yallop and C. Y. Hohenkerk, (Cambridge University Press, 1990), ISBN 0-521-38731-0, 98 pages, soft plastic cover, $19.95.

This book presents the equations and the appropriate polynomial coefficients for determining the positions of the Sun, Moon, Venus, Mars, Jupiter, and Saturn at any time on any date from 1991 to 1995.

Space Flight

Rockets into Space, by Frank H. Winter, (Harvard University Press, 1990), ISBN 0-674-7760-7, acid-free paper, 165 pages, hardcover, $22.50.

A popular survey of the development of rocketry, this book covers mainly the period since the 1950s. It also details space programs other than those of the United States and Soviet Union.

QUICK PICKS

Stars

Star Catalogues: A Centennial Tribute to A. N. Vyssotsky, edited by A. G. Davis Philip and Arthur R. Upgren, (L. Davis Press, 1989), ISBN 0-933485-10-7, 100 pages, hardcover, no price given.

Stars and Their Spectra: An Introduction to the Spectral Sequence, by James B. Kaler, (Cambridge University Press, 1989), ISBN 0-521-30494-6, 300 pages, hardcover, $27.50.

Introduction to Stellar Astrophysics, Volume 1: Basic Stellar Observations and Data, by Erika Böhm-Vitense, (Cambridge University Press, 1989), ISBN 0-521-34402-6, 244 pages, hardcover, $59.95.

The Fundamentals of Stellar Astrophysics, by George W. Collins II, (W. H. Freeman, 1989), ISBN 0-7167-1993-2, 494 pages, hardcover, no price given.

White Dwarfs, edited by G. Wegner, (Springer-Verlag, 1989), ISBN 0-387-51031-1, 524 pages, hardcover, $58.30.

Accuracy of Element Abundances from Stellar Atmospheres, edited by Rainer Wehrse, (Springer-Verlag, 1990), ISBN 0-387-52365-0, 109 pages, acid-free paper, hardcover, $32.40.

Evolution of Interstellar Dust and Related Topics, edited by A. Bonetti, J. M. Greenberg, and S. Aiello, (North-Holland, 1989), ISBN 0-444-88334-7, 462 pages, hardcover, $151.25.

Supernovae, edited by Albert Petschek, (Springer-Verlag, 1990), ISBN 0-387-97069-X, 293 pages, acid-free paper, hardcover, $59. ☐

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Meetings & Events

October 12-14
Georgia Star Party, Hard Labor Creek State Park, near Atlanta, Georgia. Sponsored by the Astronomical Society of the Atlantic. Contact: ASA, c/o Center for High Angular Resolution Astronomy, Georgia State University, Atlanta, GA 30303. Phone:(404) 264-0451.

October 18-21
8th Annual Deep South Regional Star Gaze, Percy Quin State Park, McComb, Mississippi. Contact: Mark Stauffer. Phone: (504) 359-2156 (days), (504) 273-2320 (evenings).

October 19-20
8th Annual Northern Virginia Telescope Meet, C. M. Crockett Park, Calverton, Virginia. Sponsored by the Northern Virginia Astronomy Club. Contact: Al Schumann, 6121 Rivanna Drive, Springfield, VA 22150. Phone: (703) 256-4777.

October 19-20
Twin Lakes Star Party. Sponsored by the West Kentucky Amateur Astronomers. Contact: Jim Boren, Land between the Lakes, Golden Pond, KY 42211-9001. Phone: (615) 232-7405 (days), (615) 232-6820 (evenings).

October 19-21
Astronomy Workshop '90, Camp Maskepetoon, one hour south of Edmonton, Alberta. Sponsored by the Royal Astronomical Society of Canada, Edmonton Centre. Contact: George Moores, 2415 107 Street, Edmonton, Alberta, Canada T6J 5N4. Phone: (403) 436-2855 (after 6 p.m.).

October 19-21
5th Midwest Space Development Conference, Westlake, Ohio. Contact: Midwest Space Development Conference '90, 524 West 6th Street, Lakeside, OH 43440.

October 19-21
Stella-Della-Valley IV, Ottsville, Pennsylvania. Sponsored by the Bucks-Mont Astronomical Association and the Mid-East Region of the Astronomical League. Contact: Greg Mauro, 4 Crosswicks Court, Trenton, NJ 08610. Phone: (609) 585-9465.

October 20
6th Annual Blue Ridge Parkway Regional Stargaze, Julian Price Park, near Blowing Rock, North Carolina. Contact: Greg Kirby, 12 East Street, Granite Falls, NC 28630. Phone: (704) 396-7656.

October 25-27
Great Plains Planetarium Association Annual Meeting, Kansas Cosmosphere and Space Center, Hutchinson, Kansas. Contact: Roger Hoefer, Planetarium Director, 1100 North Plum, Hutchinson, KS 67501.

October 27-28
17th Annual Astronomical Association of Northern California Conference, Lawrence Hall of Science, Berkeley, California. Contact: Don Stone, AANC, 731 Camino Ricardo, Moraga, CA 94556. Phone: (415) 376-3007.

November 2-3
Stargazing Weekend, Pennyrile Forest State Resort Park, Dawson Springs, Kentucky. Contact: Dean Henson, 20781 Pennyrile Lodge Road, Dawson Springs, KY 42408. Phone: (800) 325-1711.

November 9-10
Astronomy Weekend, Jenny Wiley State Resort Park, Prestonsburg, Kentucky. Contact: Johnny Martin, HC 66, Box 200, Prestonsburg, KY 41653. Phone: (800) 325-0142.

February 14-18, 1991
7th Annual Winter Star Party, Florida Keys, Florida. Contact: Bob or Sharon Grant, 5401 Southwest 110th Ave., Miami, FL 33165. Phone: (305) 595-8778.

March 30
Astrophoto IX, Thousand Oaks, California. Sponsored by the Ventura County Astronomical Society. Contact: VCAS/Astrophoto IX, P. O. Box 982, Simi Valley, CA 93062.

April 20
Astronomy Day. Contact: Gary Tomlinson, Astronomy Day Coordinator, c/o Chaffee Planetarium, 54 Jefferson SE, Grand Rapids, MI 49503. Phone: (616) 456-3987.

July 8-12
Research Amateur Astronomy Symposium, La Paz, Baja California Sur, Mexico. Contact: Corporation for Research Amateur Astronomy, P.O. Box 16542, San Francisco, CA 94116. □

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information.

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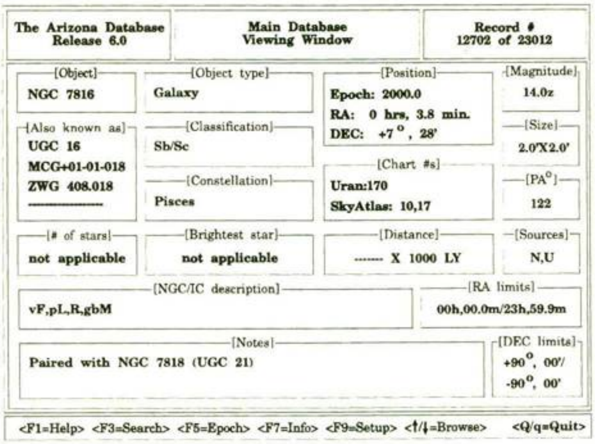

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Release 6.0

Main Database
Viewing Window

Record #
12702 of 23012

[Object] NGC 7816
[Object type] Galaxy
[Position] Epoch: 2000.0
RA: 0 hrs, 3.8 min.
DEC: +7 °, 28'
[Magnitude] 14.0z
[Also known as] UGC 16
MCG+01-01-018
ZWG 408.018
[Classification] Sb/Sc
[Size] 2.0'X2.0'
[Chart #s] Uran:170
SkyAtlas: 10,17
[Constellation] Pisces
[PA°] 122
[# of stars] not applicable
[Brightest star] not applicable
[Distance] ------- X 1000 LY
[Sources] N,U
[NGC/IC description] vF,pL,R,gbM
[RA limits] 00h,00.0m/23h,59.9m
[Notes] Paired with NGC 7818 (UGC 21)
[DEC limits] +90°, 00'/
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<F1=Help> <F3=Search> <F5=Epoch> <F7=Info> <F9=Setup> <↑/↓=Browse> <Q/q=Quit>

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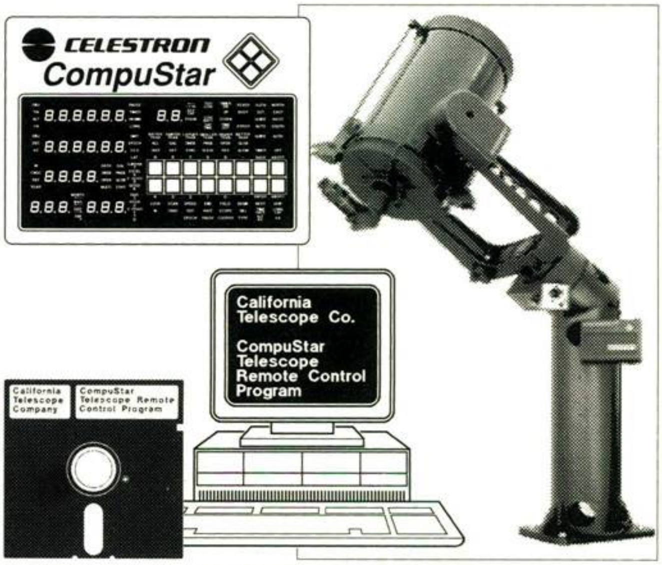
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Readings and Resources

HST (page 30)

Astronomical Optics by Daniel J. Schroeder, (Academic Press, 1987). Good background material (but rather technical) on optical aberrations in telescopes, with particular application to the *HST.*

The Space Telescope Observatory, NASA CP-2244, NASA, Washington, DC, 1982.

Astronomy Looks to Future (page 34)

"The Telescope That Defies Gravity," by Richard Berry, ASTRONOMY, July 1988. An in-depth look at the unique design of the Keck Telescope's optical system and what kinds of astrophysical research astronomers plan to carry out with the 10-meter instrument.

New Technology Telescope (page 44)

The New Technology Telescope, (European Southern Observatory, 1990). A 32-page booklet describing the NTT, its unusual active optics system, and the science being done with the telescope. Contains a wealth of high-resolution images taken with the NTT.

Telescopes for Astrophotos (page 72)

Astrophotography for the Amateur by Michael Covington, (Cambridge University Press, 1985). Though quickly becoming out-of-date, this is still the best introduction to amateur astrophotography in book format on the market. Recommended for anyone interested in learning how to take astronomical photos, both with and without a telescope.

CREDITS

Cover: Jack Newton, 25-inch f/5 Newtonian, cooled Ektachrome 400 film, 6x6 cm format; *page 4:* ESO; *p. 22, top:* NASA/Goddard Space Flight Center; *bottom,* Smithsonian Astrophysical Observatory; *pp. 30-31:* IMAX Corp.; *p. 31,* STScI; *p. 32, left,* simulation by Richard Berry; *top right:* diagram by Richard Berry; *bottom right,* diagram by Richard Berry; *p. 33:* STScI; *pp. 34-35:* Roger Ressmeyer, © 1990 — Starlight from the SPACE PLACES Project; *p.34,* MMT Observatory; *p. 35,* University of California, Berkeley; *p. 36, top:* Magellan Project; *bottom:* NOAO; *p. 37;* Columbus Project Office; *p. 38:* Science and Engineering Research Council; *p. 39:* ESO; *pp. 40-41:* California Association for Research in Astronomy; *p. 42, top:* MIT Lincoln Lab; *bottom:* Center for High Angular Resolution Astronomy; *p. 43:* University of Wyoming; *pp. 44-45:* ESO; *p. 45:* Joel Harris; *p. 46:* ESO; *p. 47:* U. S. Naval Observatory; *pp. 48-49:* ESO; *p. 57:* Donald C. Parker, 16-inch f/5 Newtonian, hypered Tech Pan film, 1-second exposure, taken October 4, 1988; *pp. 62-65:* studio photos by Darla Gawelski and Chris Becker; *p. 66:* Donald C. Parker, taken August 25, 1988; *p. 67:* Bruce Bond; *p.68, top:* Donald C. Parker, taken September 21, 1988; *p.68, bottom:* Jean Dragesco, 24-inch refractor stopped to 18 inches, Tech Pan film, red filter, taken September 15, 1988; *p. 69, top:* Donald C. Parker, taken August 25, 1988; *p.69, bottom left:* Donald C. Parker, taken August 21, 1988; *p. 69, bottom right:* Donald C. Parker, taken November 30, 1988; *p. 70, top left:* Gary Rosenbaum, 8-inch f/6 reflector, 305x, June 19, 1986; *top right:* Gary Rosenbaum, 8-inch f/6 reflector, 305x, July 6, 1986; *p. 71:* Russ Sampson; *p. 72:* Tony Hallas and Daphne Mount, 5-inch f/8 apochromatic refractor, 6x7 format film; *pp. 72-74:* studio photos by Darla Gawelski and Chris Becker; *p. 75:* Alan Dyer; *p. 76:* Moon photos by Alan Dyer, 8-inch SCT, Kodachrome 64 film; *p. 76, left:* Scott Hicks, 12.5-inch f/4.8 Newtonian, 25-minute exposure; *right:* Jack Newton, 20-inch f/5 Newtonian, VR 1000 film, light pollution filter,18-minute exposure; *p. 77:* Orien Ernest, 12.5-inch f/5 Newtonian, cooled High-Speed Ektachrome film, 30-minute exposure; *p. 78:* Ben Mayer; *p. 79:* Gregory Field; *p. 80:* Phil Harrington, 8-inch f/5 reflector, at 55x; *p. 81, left:* Jack B. Marling, 18-inch f/4.4 reflector, hypered Fujichrome film, 20-minute exposure; *right:* Jack B. Marling, 18-inch f/4.4 reflector, hypered Fujichrome film, 20-minute exposure; *p. 83, top:* Jack Newton, 8-inch f/10 Schmidt-Cassegrain, T-scanner, hydrogen-alpha filter, taken July 21, 1990; *center:* Thad Fuller, taken July 21, 1990; *bottom:* Clark B. Snure, 300mm lens, taken July 21, 1990; *p. 84-85:* Roy Gephart, 300mm f/6 lens, Kodachrome 64 film, 1/30-second exposure on July 21, 1990; *p. 84, bottom left:* Chris Schur, 14-inch f/5 reflector, hypered Tech Pan film, 15-minute exposure; *bottom right:* Paul Shulins, 50mm f/2.8 lens, Kodacolor 400 film, 25-second exposure, July 29, 1990; *p. 85, bottom left:* Nelson Falsarella, 8-inch f/6.5 reflector with CCD video camera, taken July 5, 1990; *bottom right:* Ernie Piini, 3.5-inch f/15 Maksutov telescope, Ektar 25 film, neutral density filter, 1/60-second exposure on July 21, 1990; *p. 86:* sketches by Jose Olivarez, 16-inch reflector, 150x, February 25 and May 22, 1990.

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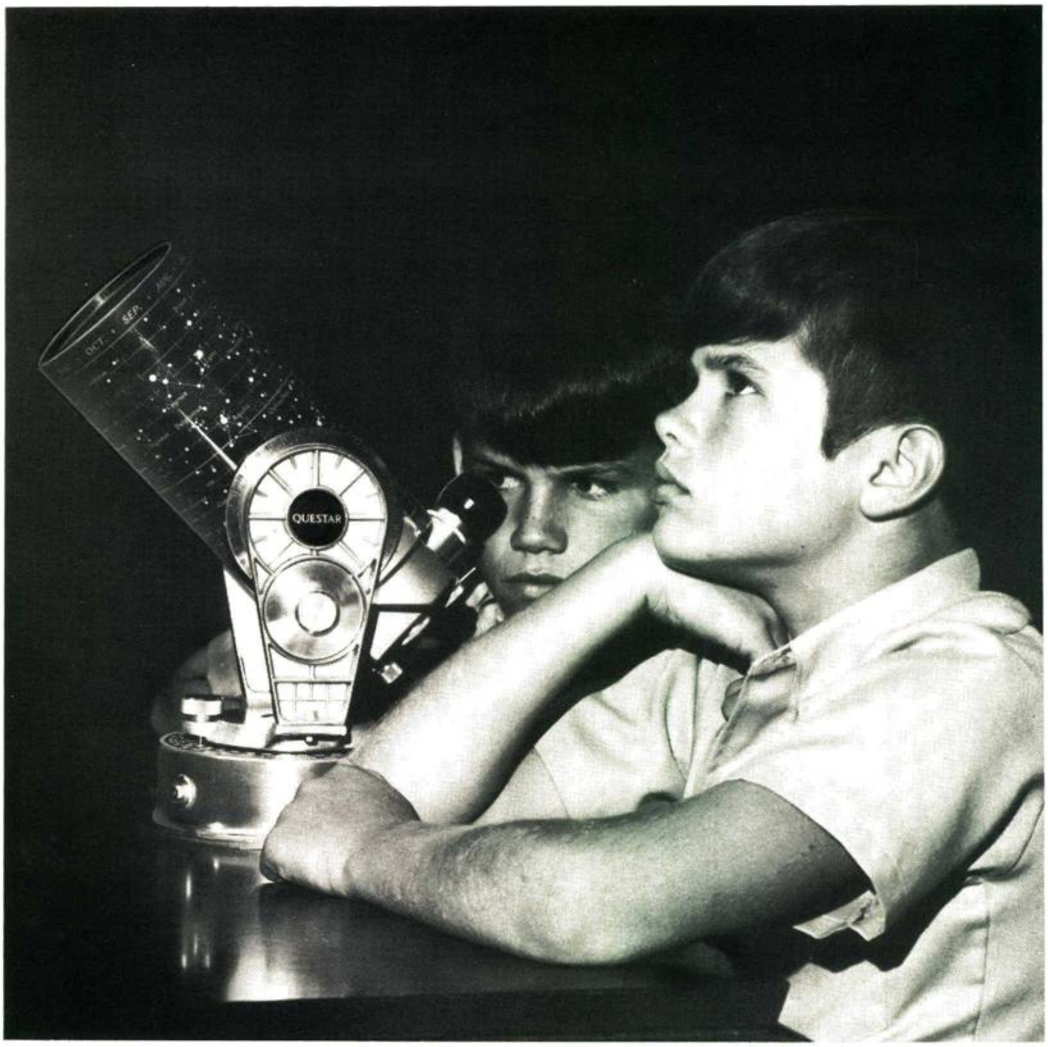

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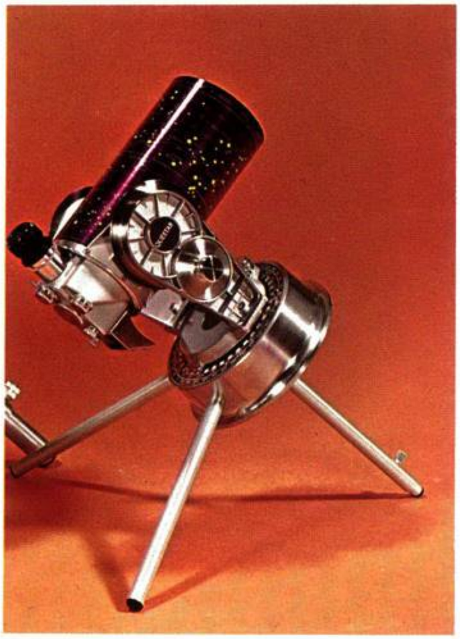

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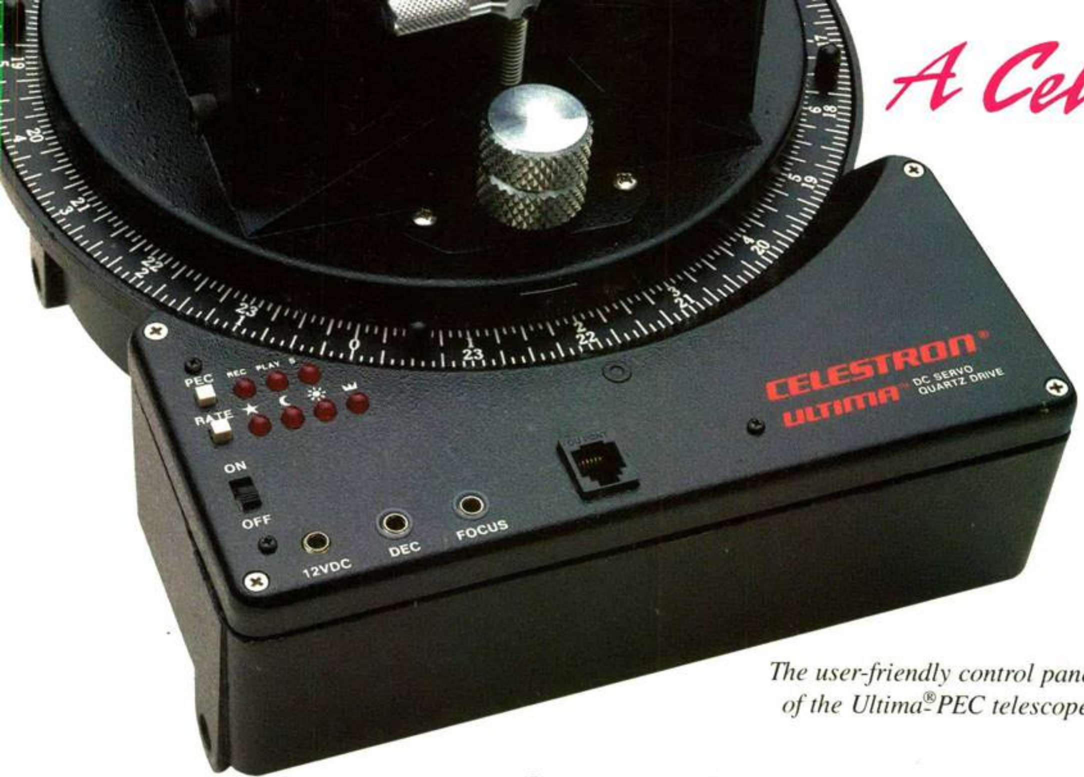

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